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Automation of the stone materials dosing process, controlled by variable frequency drives

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ABSTRACT

The objective of this article is to determine to what extent the automation of the stone materials dosing process, controlled by sequential drive of frequency variators, contributes to improving the productivity of a company dedicated to the production of asphalt in Peru for which, initially, the characteristics of the procedure that will lead to achieving the automation will be described. The results will then be displayed with respect to the indicators used to compare productivity before and after automation. The automation will be done by means of the logo 230RE controller, which will be connected to three frequency inverters, the programming development will be through the logo soft comford V8 software, for the sequential actuation, timers with connection delay will be used. Applying the automation, it is possible to improve the annual efficiency by an average of 58.30%, this is reflected in the monthly decrease in production time by 13.92%, in turn increasing the amount of stone material produced by an average of 43.77%. Likewise, it is possible to significantly reduce the production loss capacity by an annual average of 93.99%.

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1. INTRODUCTION

In these times, many industrial and manufacturing companies are facing a more demanding market [1], and it is not only the price but also the quality of the product [2], that is why companies have now focused on taking actions to improve their product [3], that is why they invest in improvement projects, in order to maximize the resources used and obtain better productivity [4]. Organizations seek every day to achieve greater productivity in their production processes [5], in order to be more competitive, that is why they develop strategies that are supported by technology [6]. Thus, competitiveness and globalization require efficient responses from companies [7], and strategies that allow them to survive in a world in constant change and reduce waiting times for customers [8].

In this competitive context demarcated by incessant technological change [9], it is imperative to restructure production processes relying on industrial automation [10]. By automating a process, it is possible to improve productivity, reducing downtime, and eliminating defects or errors during the production process, due to the lack of precision of activities carried out by operators [11], [12]. It is that globalization in recent years has allowed the expansion in learning and knowledge for the management of automation and control technology [13]. The importance of the automation of industrial and manufacturing processes is to increase productivity [14], [15]. Automation has thus become one of the best tools that have contributed to the systematic reduction of costs and production times [16], [17], achieving higher productivity and better product quality [18]. Likewise, automation within its advantages provides increased productivity, through the optimal use of resources when making use of electronic instrumentation [19], [20]. In this sense, industrial processes, at this time, are migrating to a state of automation, in which they make use of various techniques on process control [21]-[23].

However, one of the areas where the use of industrial automation is necessary is that of the processes related to the dosage or mixing of stone materials [24] and it is that many of the asphalt plants do not have basic automation levels to guarantee high-quality products to its customers [25]. The increasing technification that the industrial sectors has been having [26]; organizations and companies dedicated to asphalt mixtures find it necessary to optimize the processes they currently carry out in order to maintain and increase the demand for their products [27]. It turns out, then that automation plays an important role in the processes that are responsible for manufacturing asphalt mix in a plant [28]. The way this product is made requires optimal control loops to achieve levels according to consumer expectations [29]. There are cases of companies dedicated to the production of asphalt that cannot supply the current demand, due to the fact that their processes are manual that lead to operating errors [30]. These control processes are often supported by the benefits of working with frequency inverters [31]; since the frequency variators allow to control the power frequency of a motor in alternating current, reducing the starting current, and ease to control a process at will [32].

In this sense, this article aims to determine to what extent the automation of the stone materials dosing process, controlled by sequential drive of frequency inverters, contributes to improving the productivity of a company dedicated to the production of asphalt in Peru. For which, initially the characteristics of the procedure that will lead to achieving the automation will be described. Then the results will be shown regarding the indicators used to compare productivity before and after automation.

2. RESEARCH METHOD AND RELIABILITY ANALYSIS

2.1. Research method

The research method is quantitative and experimental in design, because two scenarios for data collection are identified. The first is linked to the process in its initial state (stone materials dosing process) without automating and then it is the automated process. Based on the above, we proceed to analyze the productivity indicators, in the search to determine to what extent the automation of the stone materials dosing process, controlled by the sequential drive of frequency inverters, contributes to improving the productivity of a dedicated company to the production of asphalt. For which, the characteristics of the procedure that will lead to achieve automation will be described. The results will be shown below with respect to the indicators used to compare productivity before and after automation. The automation will be carried out through the logo 230RE controller which will be connected to three frequency converters, the programming development will be through the logo soft comford V8 software and for sequential action timers with connection delay will be used.

According to the objectives to be developed in this scientific article, then we proceed to initially show the findings related to the productivity indicators. Which are efficiency (actual production and estimated in m^3/hr) and the production loss capacity (plant capacity and effective capacity in m^3/hr), which will make it possible to determine to what extent the automation of the stone materials dosing process, controlled by sequential drive of frequency variators, contributes to improving productivity. It should be noted that the data collection was obtained from the application of a record sheet, which represents the instrument for measuring the data. In terms of the techniques to apply, these were observation and documentary analysis, due to that the information on the indicators was provided by the company dedicated to the production of asphalt in Peru. Said indicators correspond to the values obtained daily in the period of one month.

2.2. Reliability analysis of the data

At this point we proceed to validate the reliability of the data collected for each of the indicators that correspond to the variable under analysis, this analysis will be for each of the systems both manual and automatic will be carried out through the alpha coefficient of cronbach using the statistical software statistical product and service solutions (SPSS) V25. In Table 1, it is observed that there is a high degree of reliability of the data collected both in the manual and in the automatic systems, because the value of the cronbach's alpha coefficient for both cases is greater than 0.90. Also, Table 2 shows the result of the reliability analysis if one of the indicators was not considered in the research; It is evidenced that cronbach's alpha for any of the cases is higher than 0.904, in this way the data obtained through the collection instrument are validated.

Table 1. Cronbach's alpha for the data collected

Systems under analysis	Cronbach's alpha	Cronbach's alpha based on standardized elements
Manual system	0.932	0.932
Automatic system	0.913	0.922

Table 2. Cronbach's alpha of the automatic system indicators

Indicators	Cronbach's alpha Manual system	Cronbach's alpha Automatic system
Actual production (m^3/hr)	0.981	0.911
Estimated production (m^3/hr)	0.921	0.955
Production time (hr)	0.904	0.925
Efficiency	0.943	0.913
Loss capacity (m^3/hr)	0.911	0.906

3. PROCEDURE

Like any automated process, both the force or power circuit and the control circuit must always be identified. This last circuit will be governed by a programmable logic controller, whose programming logic through the circuit diagram is also described in the following point.

3.1. Description of the automated process

Next, I will proceed to describe the process to automate:

- Pressing the start button will automatically open the gates of the three storage hoppers for stone aggregates, such as sand, gravel and gravel, in the proportion of 50%, 35% and 15%, respectively. When the gates are opened, each one of them will take a certain time so that they can empty the sand, gravel and gravel, said time was defined by the operations area, these being 300 seconds, 210 seconds and 90 seconds, respectively.
- Sequentially and automatically, the 5HP motors of the conveyor belts will be activated working at an average speed of 1800 revolutions per minute (RPM). These speeds will move the components for the asphalt mixture during a period of 300 seconds to automatically slow down, a speed of 600 RPM; this reduction will be made possible thanks to the frequency inverter connected to the programmable logic controller. The time in which the conveyor belt will work at its minimum speed will be determined by each scale-type weight sensor, who by determining the exact weight of each component of the asphalt mix, will stop the conveyor belt motor and open the valve for the emptying of said components on a collecting strip.
- This collector strip will carry the three components simultaneously, so the operating condition at this stage is that the three valves are open, until the sand, gravel and gravel emptying process is completed. The time determined for this stage is 240 seconds; then the entire mixture will be poured into the oven, which contains two chambers. However, it is important to specify that in the inner chamber, the three components will be further mixed with asphalt and dried by an open fire explosion. This is due to a fan and a micrometric sprinkler that makes it have an intense and permanent fire towards the inner chamber. In addition, they dry the material to remove moisture, operating at a drying temperature of 400° C. Once the drying is finished, it goes to the second chamber where it is mixed with the asphalt cement. In this second chamber, there are mixing blades that allow uniformity with the asphalt and stone aggregates. Once mixed, it falls into a silo where the asphalt is stored and from there it is raised by a drag chain to the bottom to a height of 3.5 meters. It's where two buckets of asphalt mix are stored and the door opens when the dump truck parks at the bottom of the pothole, dispensing the hot asphalt. A summarized architecture of automation is shown in Figure 1.
- In relation to the power circuit, Figure 2 shows the simulation of the circuit using the Cad Simu in which the three motors are observed (E1: motor that moves the conveyor belt that will dose with sand, E2: motor that moves the conveyor belt that will dose with gravel and E3: motor that moves the conveyor belt that will dose with gravel). Each one with its corresponding 6HP/three-phase/210-250VAC/IP20 frequency variator. This also shows the power circuit of the conveyor belt motor that injects the mixture into the oven.

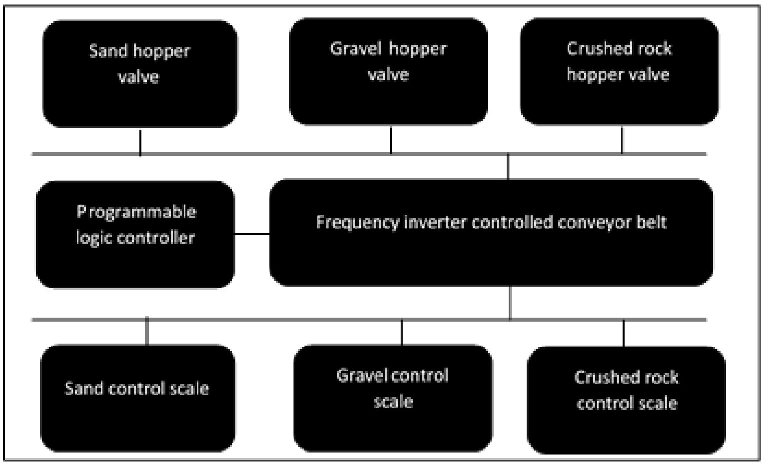

Figure 1. Architecture of the sequential drive automation with frequency inverter

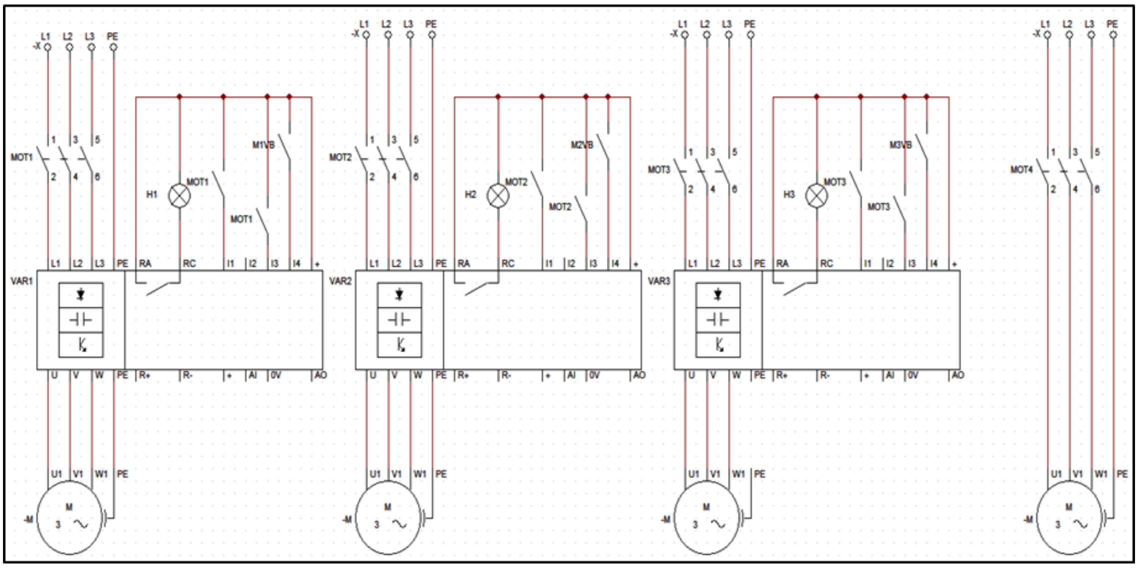

Figure 2. Power circuit of the stone materials dosing process, controlled by sequential drive of frequency inverters

- Another aspect that complements the automation is the programming of the programmable logic controller (PLC) that will allow the drive to develop sequentially; this is because delayed timers will be used in the programming of the logo 230RE controller, using the logo soft comford V8 software. Figure 3 shows the first part of the programming in the PLC; in the first segment, I2 represents the start button, which when pressed will automatically open the valves of the sand, gravel and crushed rock storage hoppers, which are represented by the coils Q1, Q2 and Q3, respectively.
- Each of these gates will be open until the emptying of each of the components is carried out, the reference time configured in the programming is determined by the timers T001 (Sand), T002 (gravel) and T003 (crushed rock).
- In Figure 4, the second segment of the programming of the stone aggregates dosing process as shown in. Where Q4 represents motor 1 of the conveyor belt that will have an operating time of 300 seconds at an average speed of 1800 RPM, said time is represented by the timer T004. After that time, the speed will be reduced to 600 RPM, through the frequency variator, represented in the programming by the mark M1 and whose actuation time will be determined by the coil of scale 1 (sand hopper) being represented in programming by coil Q5.

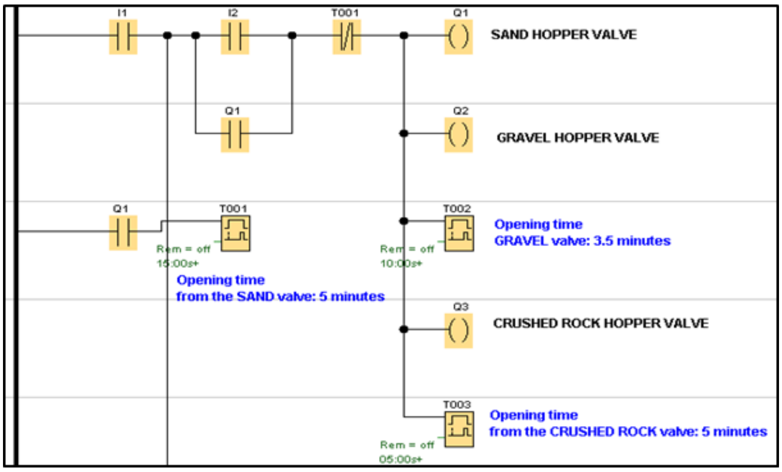

Figure 3. First segment of programming in logo soft comfort V8 software

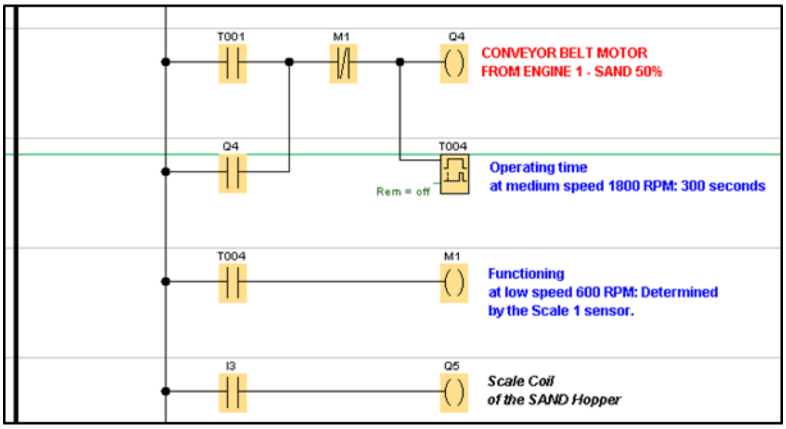

Figure 4. Second segment of programming in logo soft comfort V8 software

- In Figure 5, the third segment of the programming of the stone aggregates dosing process as shown in. Where Q6 represents motor 2 of the conveyor belt that will have an operating time of 300 seconds and with an average speed of 1800 RPM, representing by the timer T005. After the time has elapsed the speed will be reduced to 600 RPM, by means of the frequency inverter, this is represented by the M2 mark and will be determined by the coil of scale 2 of the gravel hopper, represented in programming by coil Q7.

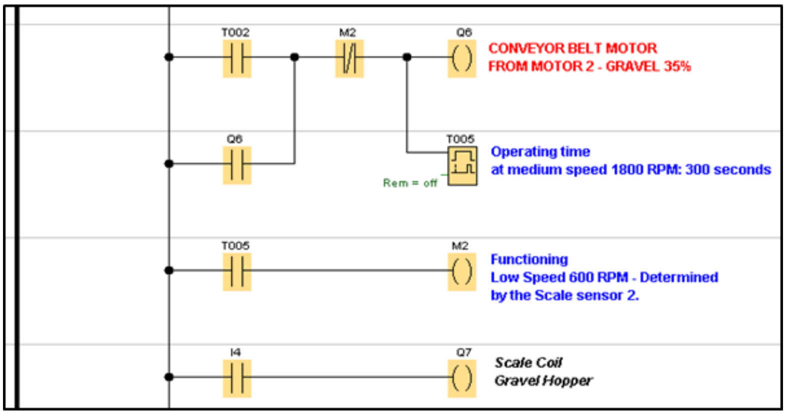

Figure 5. Third segment of the programming in the software logo soft comfort V8

4. RESULTS AND DISCUSSION

Now we will proceed to carry out the comparative analysis of the data collected in the manual system and in the automatic system, of the productivity indicators.

4.1. Results

The results obtained will be described as part of the analysis of the behavior of the indicators under study in the production period of the process, which is 11 hours per day; in relation to the efficiency indicator, which is obtained by dividing the actual production quantity by the estimated production quantity (m3/hr). Given that the total production capacity per hour is 120 m3/hr.

The production time occurs in periods of 1 hour (60 minutes) and considering that the estimated production is 118 m^3/hr. In the period from 11 hours of production, the average efficiency in one day when the manual system was applied was 62.40%. This being a very low value for the profitability of the company, as can be seen, the highest production peak was 82 m^3/hr. This value is well below the estimated production of 118 m^3/h.

In the search for improvement through automation, it is observed in Figure 6 that the average efficiency in a day once the automatic system is applied is 99.80% as can be seen the highest production peak is 118.7 m3/ h. This value is above the estimated production of 118 m^3/h. Likewise, it can be established that the average production time in a day. In the manual system, was 10.39 hours in which a total of 810 m^3/hr was produced on average with the automatic system the average production time in one day it decreases to 9.06 hours and the amount of production increases to 1295.5 m^3/hr. This can translate into an optimization per day of 12.80% of production time and a daily increase in efficiency of 59.93%. As shown in the automatic system, more production is achieved in less time. Once the parameters that are part of the efficiency indicator have been specified, the results obtained in the period of one month are shown, through a comparative analysis, with respect to the variation in the amount of real production.

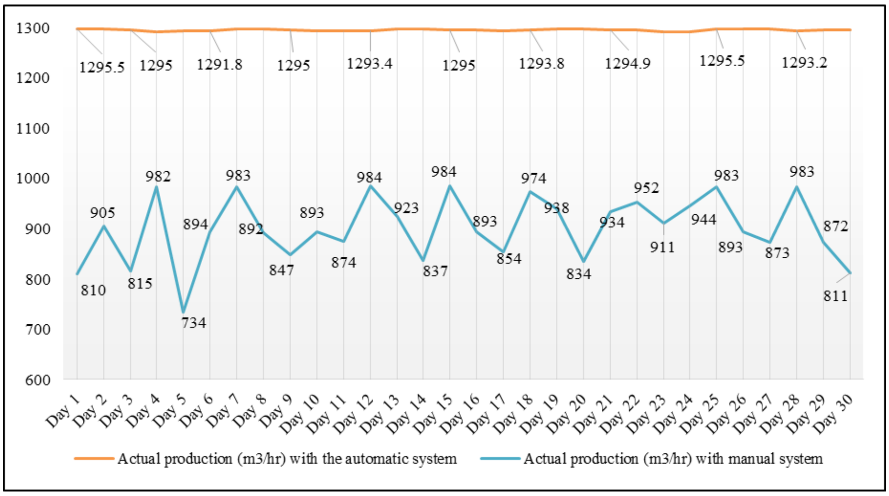

Figure 6. Monthly comparative analysis of real production (m^3/hr)

From the results represented in Figure 7, it can be said that daily production increases, when the system went from manual to automatic, this increase on average is from 27,006 m^3/hr to 38,825.2 m^3/hr, with this also the time of production at a monthly average of 13.92%, these results represent an improvement in monthly efficiency of 43.77% (December-January). This reflects an average efficiency improvement of 58.30% per year.

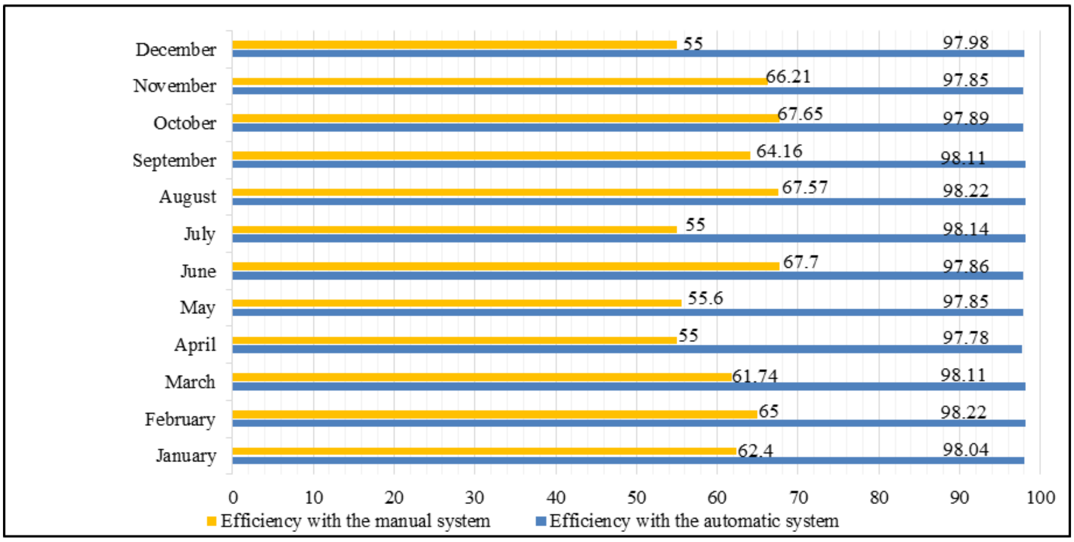

Figure 7. Annual comparative analysis of the efficiency indicator

4.2. Discussions

In relation to the discussion of the results, the following can be specified:

- By automating the dosing process of stone materials, it is possible to increase the monthly production from 27,006 m^3/hr to 38,825.2 m^3/hr and decrease the production time by a monthly average of 13.92%, thereby achieving an improvement average monthly efficiency of 43.77%. These results are achieved because by automating the dosing process, it is possible to comply with the exact amounts of aggregates such as sand, gravel and gravel, this due to the decrease in human error. These results agree with those obtained in [33] where it is pointed out that the automation system allowed to reduce the production time by 40%, this due to the parallel processes that can be carried out by the interface, allowing to improve the performance in cubic meters, which is reduced in less man and machine hours.
- Similarly, in the investigation of [34], it is concluded that the production of the concrete process has increased by an approximate percentage of 118%; since before the implementation of the automated system, only the maximum capacity generated by 2 mixers per hour was produced, which is equivalent to 12 cubic meters.
- On the other hand, the automaticity of the stone materials dosing process allows the monthly production loss capacity to improve, reducing its value by an average of 93.84%. These results are consistent with that established in [35], where it is stated that it was possible to reduce the amount of crushed rock inputs, by establishing an automatic system in the concrete plant; thus demonstrating the effectiveness of automation by reducing the amount of inputs in production and the amount of material discarded due to errors in the dosing process of the mixture.
- In general, the results of the industrial automation of the asphalt mixing process make it possible to improve the precision in the dosage of inputs and increase productivity. In this regard, in [36], [37] they point out from automation, the information on the characteristics of the composition of the mixture was obtained accurately and in real time. Also in [38], the author concludes that his design of a supervision and control system for the asphalt mix production process allows a reliable and understandable operation of the process; since it permanently has information on how the plant is working in relation to its production, alarms, configuration and trends in productivity indicators; the same ones that allow to improve or correct if it is the case the precision of the dosage of supplies by means of the calibration of scales. These results support and support the results obtained in this research.

5. CONCLUSION

By developing the sequential drive by means of the logo 230RE controller which is interconnected to three frequency inverters and making use of the logo soft comford V8 software, it is achieved: annual efficiency improves by an average of 58.30% in the stone materials dosing process, this is reflected in the monthly decrease in production time by 13.92%, in turn increasing the quantity produced by an average of 43.77%. To continue improving productivity, it is recommended to establish a maintenance plan to monitor the insulation of electric motors, in order to avoid any stoppage in production. Significantly decrease the production loss capacity by an annual average of 93.99%, because the loss on average decreased from 12,594 to 774.8 m3/hr. To further optimize productivity, it is recommended to regularly monitor and calibrate the hopper scales to ensure the quality of the stone materials. Finally, it is concluded that programmable logic controllers, including those of medium or low range, allow to be coupled to the architecture of control of the processes related to the industry of the dosing of stony materials for processes of elaboration of asphalt mixtures.

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