Kiln Predictive Maintainance

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1 Introduction

In today's world, cement is the basis for civil engineering and its applications. The world cement production has grown in a constant manner since the early 1950s. During the past few decades, new innovations in the production chain have become necessary, as well as an increased need for a high level of automation, also due to the complex chemical and physical processes involved. The main problems associated with alternative fuel combustion in the modern cement plant, however, is the increased possibility of cyclone blockages, ring formation and corrosion, mainly caused by volatile elements (Sulphur, chlorine, and alkali compounds), which tend to condense and accumulate on cold spots in the combustion areas.

In addition, the study in a cement plant in a western Asia in one of the cement production lines have predicted the strong correlation between SO2 values measure in the kiln inlet area and occurring cyclone blockages.

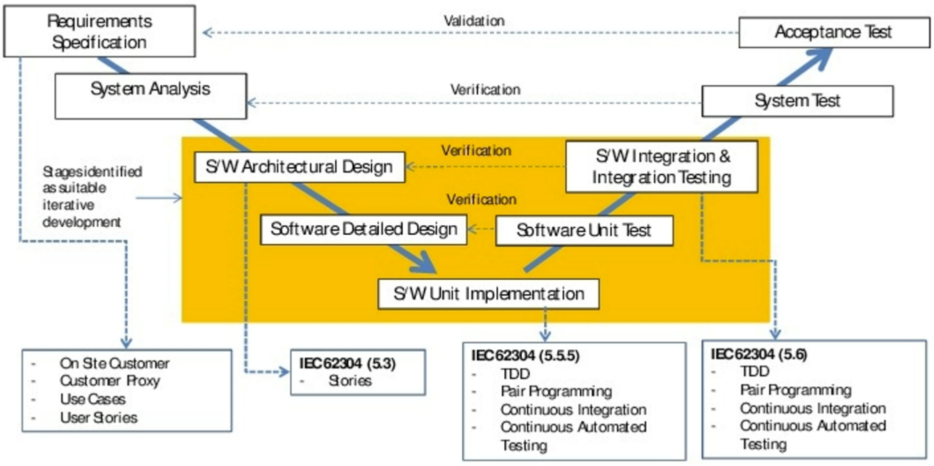
Therefore, this study has motivated us to present the work Kiln Predictive Maintenance System, that will initiate predictive maintenance tasks before unwanted kiln shutdown occurs. The idea of the proposed system is to analyze the parameters from the sensors installed on the kiln inlet area as well as to optimize the cyclone blockages. Based upon the parameter measurement, the system gives the overview of the kiln dividing the risks into 2 major categories.

- Green: the system generates the warning alarm if there is no risk associated in the blockage.
- Yellow: the system generates the warning alarm if the risk associated in the blockage is low.
- Red: the system generates the warning alarm if the risk associated in the blockage is high.

2 Major Requirement

Analyse kiln gases (SO2), predict probability of cyclone blockages, downtime and indicate need for maintenance.

3 Process Model



4 Team Organization

- Front End Team, Back End Team, Quality Assurance, Documentation and Reporting.

5 Task Distribution

The task allocation of the phases like design, coding, testing, documentation and coding are equally distributed among the four members.In addition, activities in defining the task, reviewing each other work effort are done in the collaboration manner.

6 Project Plan

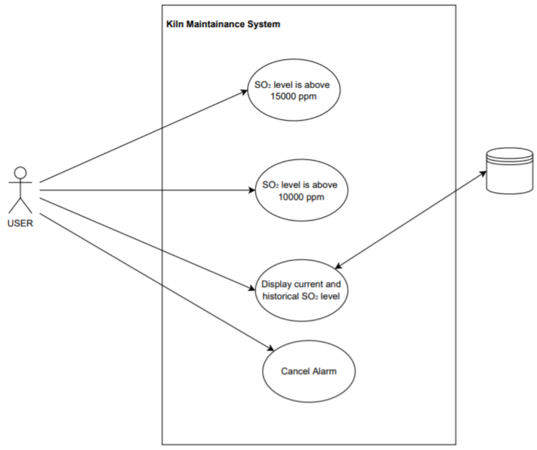
Activity Plan	**Week 1**	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**	**Week 7**	**Week 8**	**Week 9**
Requirements Analysis									
Design and Implementation									
Development									
Testing and Verification									
Deployment									

7 Risk to the Project

- Requirement analysis and understanding
- Real-time behaviour of connected modules and devices
- Involvement of user with end system

8 Use Cases

8.1 Use Case Diagram



8.2 Use Case Description

Use Case Identifier	UC 1: Red Flag Indicator
Version	0.1
Description	The system alerts by indicating red flag when the SO^2 level rises 15000 ppm
Actor	Operator
Pre-Condition	The proper detailed SO^2 level should be examined
Post-Condition	The system should be able to alert with red flag when it exceeds the threshold
Failure Scenario	The proper implementation of the SO^2 level does not reflect in the red flag indicator
Actor Intentions	Examine the SO^2 level
System Responsibilities	System identifies that the kiln SO^2 level is over 15000 ppm. System indicates and sends red flag alerts to the operators.

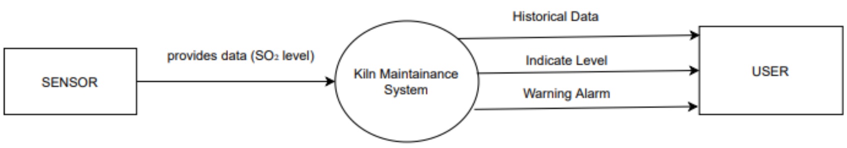
Use Case Identifier	UC 2: Yellow Flag Indicator
Version	0.1
Description	The system alerts by indicating yellow flag when the SO^2 level rises 10000 ppm
Actor	Operator
Pre-Condition	The proper detailed SO^2 level should be examined
Post-Condition	The system should be able to alert with yellow flag when it exceeds the threshold
Failure Scenario	The proper implementation of the SO^2 level does not reflect in the yellow flag indicator
Actor Intentions	Examine the SO^2 level
System Responsibilities	System identifies that the kiln SO^2 level is over 10000 ppm. System indicate and sends yellow flag alerts to the operators.

Use Case Identifier	UC 3: Historical SO^2 Level
Version	0.1
Description	The system displays current and past SO^2 level events
Actor	Operator
Pre-Condition	The proper detailed SO^2 level should be examined and stored in the database
Post-Condition	The system should be able display past and current events in several representations
Failure Scenario	The proper implementation of the SO^2 level does not reflect in the representation of the events.
Actor Intentions	View current and past SO^2 level
System Responsibilities	Loads all the data from the database. Displays the graphical representation on the UI level. Displays probability of cyclone blockage.

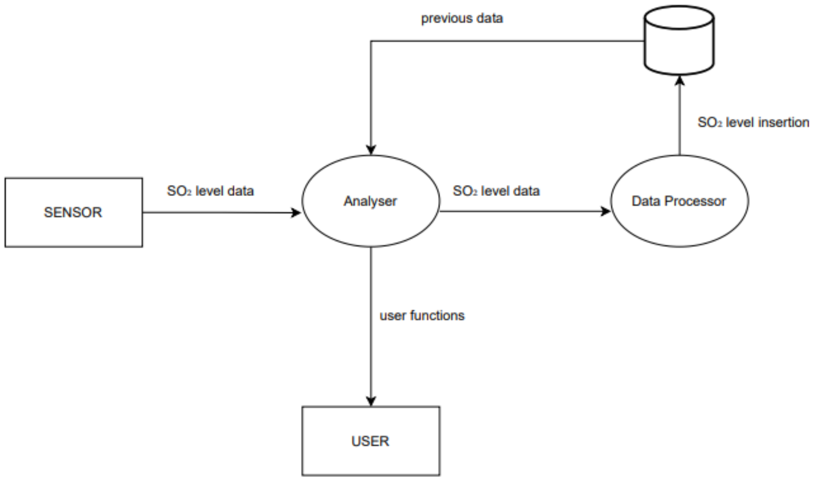
Use Case Identifier	UC 4: Cancel Alarm
Version	0.1
Description	The system allows to cancel the activated alarm
Actor	Operator
Pre-Condition	The alarm must be activated
Post-Condition	The alarm must be cancelled
Failure Scenario	The running alert alarm is still on after the cancellation alarm is triggered.
Actor Intentions	Stop the current activated alarm
System Responsibilities	Cancellation of the alarm sound.

9 Data Flow Diagram

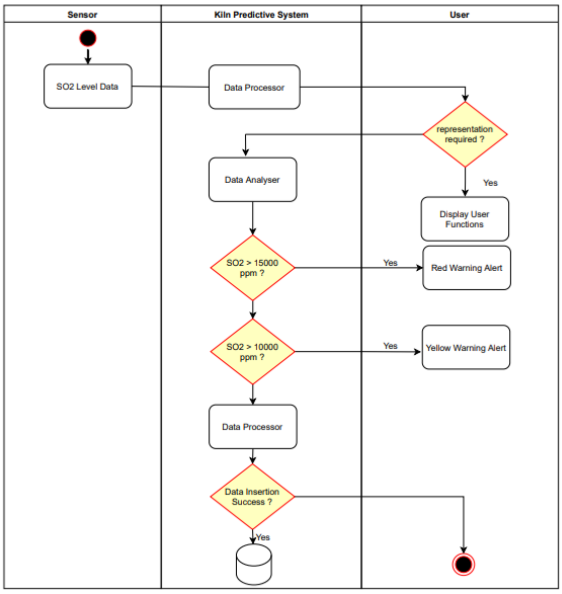
9.1 Context Diagram



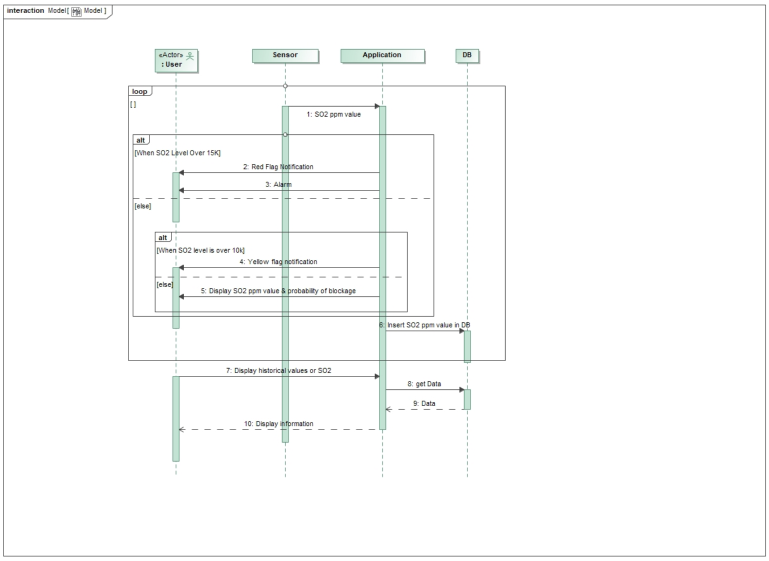
9.2 DFD 1 Diagram



10 Activity Diagram

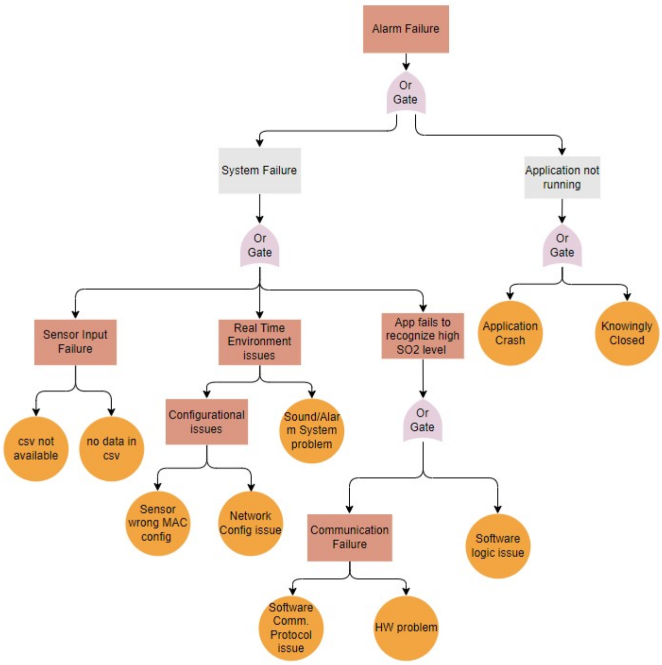


11 Sequence Diagram



12 Hazard Analysis

12.1 Fault Tree Analysis



13 STAMP Analysis

13.1 Hazards

H1: So2 level not received to the application.
H2: Alarm/Notification not received.
H3: Alarm/Notification received late.
H4: Wrong prediction of Kiln blockage.
H5: Wrong level of Alarm/Notification received/raised.
H6: Application does not provide correct historical values.
H7: Application does not provide correct level representation.
H8: Application raises false alarm.
H9: Application does not show clear information on the UI.
H10: Alarm sound is not distinguishable from general sound.
H11: Alarm/Notification is allowed to suppress by any user.
H12: Application have unmanaged sensitive data.

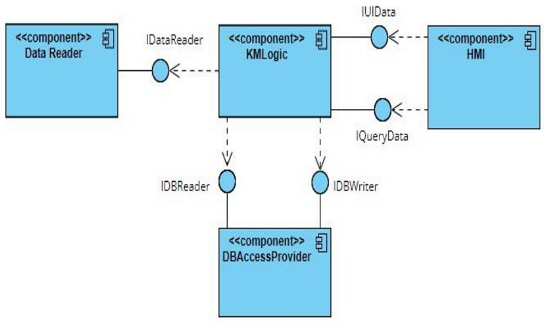
13.2 Safety Requirements and Safety Constraints

Hazards	Safety Requirements	Safety Constraints
H1	The system must receive the correct sensor (csv) data	1.Sensor must be configured properly and validated during installation. 2. Application must receiver data from sensor every 1 minute 3. Application must validate sensor connection on every restart.
H1	If the sensor (csv) data is unavailable, then the violation must be detected, and measures must be taken to prevent loss	Application must show a high priority alert in case of the missing three consecutive sensor payload
H2	Alarm must be indicated under worst-case running environments	The system must generate the alarm within 0-15 seconds in case of violations
H3, H8	Alarm must be received correctly within the specified range of 0-15 seconds under worst-case running environments	The system must generate alarm correctly within the specified range of 0-15 seconds in case of violations.
H4	The system must correctly predict the Kiln blockage under worst-case running environments	1. Update Kiln blockage prediction every 2 hours. 2. Timestamp all the predictions
H5	The system must ensure the correctness of the alarm indication	1. Application must append so2 ppm level and timestamp with alarm 2. Alarm requirements should be tested rigorously.
H6, H7, H9	The system must display the statistical representation of the data correctly and clearly	1. Application must show SO2 ppm value and date time on the graph for every data point. 2. Representation must be thoroughly tested.
H10	The alarm indication on the system must be uniquely identifiable for each of the alarms	1. Yellow alarm sound should be distinctive and differentiable from red alarm 2. Red alarm sound should be distinctive and differentiable from yellow alarm
H11	The system should allow the authorized user to cancel or suppress the alarm only	1. Application must validate username and password before providing access elevated privileges. 2. Application must validate authorization to suppress/cancel alarm. 3. Application must log username against alarm cancellation.

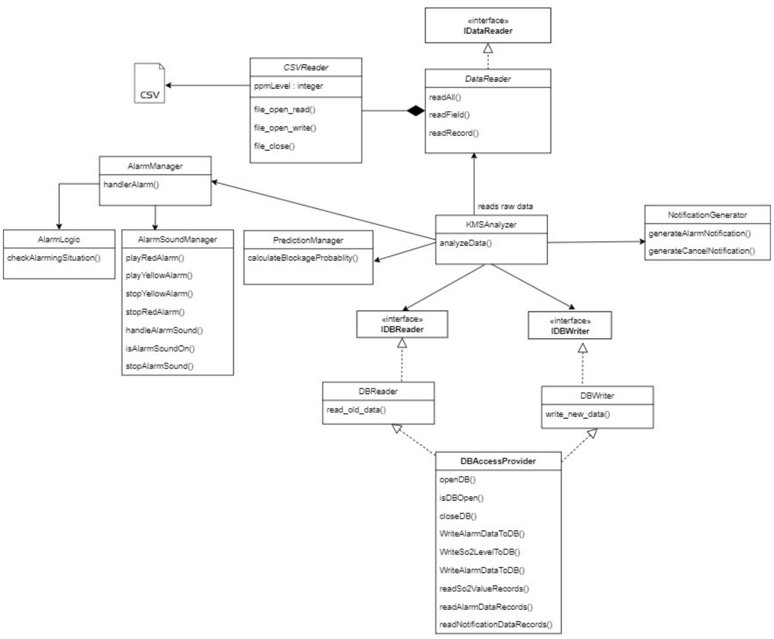
13.3 Security Requirements and Security Constraints

Hazards	Security Requirements	Security Constraints
H12	The system must encrypt the critical data in the database	Application must encrypt username and passwords in the database.
H12	Databases should not be accessible to unauthenticated and unauthorized entities.	1. Application should be sole owner of the database. 2. Databases should be password protected and kept at secure application location.

14 Architectural Diagram



15 Class Diagram



16 COCOMO II Model

Based upon the estimated function points which are translated into LOC defined on our projects. PM = A × SizeB [PM is an effort for the project in person months.] A=2.5 [a constant value representing nominal productivity.] If B= 1 then there is a linear relationship between effort and size of product. For the early design level, value of B is supposed to be above 1 which means rate of increase of effort increases as size of product increases B is greater than 1. As the value of B can be calculated in our case therefore:
Precedentness = experience in similar projects, which is Average 3.72. **Development Flexibility** = degree of flexibility in development process,that accounts low 4.05. **Architecture risk and resolution** = degree of risk analysis being carried out,Very High 1.41. **Team Cohesion**= team management skills of the employees developing the project, Average 3.29. **Process maturity** for a process to be mature, it needs to be complete, capable to continued improvement through qualitative measures and feedback, Very high 1.56
Value of B is between 0.91 and 1.23 with 0.91 to be the best case scenario.
Value of B = 0.91 + 0.01 * (3.72+4.05+1.41+3.29+1.56) = 0.91 + 0.1403 = 1.0503
B=1.0503
Therefore,the rate of increase of effort will increase if the size of the product is increased.
Concluding, **PM** = 2.5 + 1.0503 = 3.5503 is the effort for the project in person month on the basis of early design stage level.

// Post Architecture Level Software product actual development and maintenance occurs at the Post Architecture Level. There are 17 effort multipliers used in COCOMO –II Post Architecture model.

EM (17 Scaling Factors): -

Required Software Reliability (RELY): - Very High "Risk to human life" = 1.26 Data Base Size (DATA): - Database Size / Program Size (SLOC) = 16000/1550 = 10.32 = Nominal = 1 Product Complexity (CPLX): - average of below = 0.922 Control Operations: - Nominal = 1 Computational Operations: - Low = 0.87 Device dependent Operations: - Low = 0.87 Data Management Operations: - Low = 0.87 User Interface Management t Operations: - Nominal = 1

Required Reusability (RUSE): - Low =¿ 0.95 Documentation match to life-cycle needs (DOCU): - Nominal =¿ 1

Platform Factors: Execution Time Constraint (TIME): - Nominal = 1 Main Storage Constraint (STOR): - Nominal = 1 Platform Volatility (PVOL): - Low = 0.87

Personnel Factors Analyst Capability (ACAP): - Nominal = 1 Programmer Capability (PCAP): - Nominal = 1 Applications Experience (AEXP or AEXP): - Nominal = 1 Platform Experience (PEXP): - Low = 1.09

Language and Tool Experience (LTEX): - Low = 1.09 Personnel Continuity (PCON): - Very High = 0.81

Project Factors Use of Software Tools (TOOL): - Very High = 0.78 Multisite Development (SITE): - Very High = 0.86 Required Development Schedule (SCED): - Nominal = 1

SFj (5 Scalling Factors):- 15.04 PREC : - Nominal = 3.72 FLEX : -Nominal = 3.04 RESL: - Very High = 1.41 TEAM: - High = 2.19 PMAT: - Nominal = 4.68

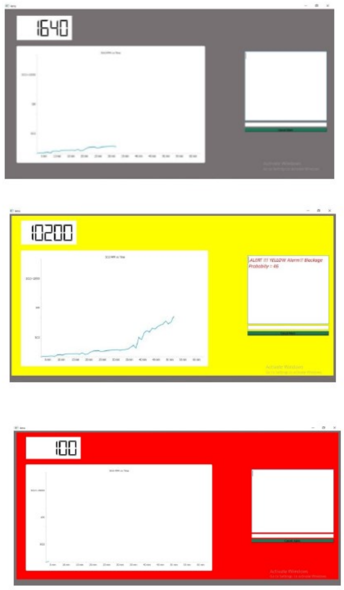
PM = A . SizeE x i=117 EMi + PMAuto = 2.94 * 1.51.064 * 0.40816+ PMAuto = 1.847 + 0.00125 =1.842 E= B + 0.01 x $_{(}j = 1)^5 SFi = 0.91+0.01*15.04 = 1.064 PMAuto = (AdaptedSLOCx(AT/100))/ATPROD = (1500*20$

A= 2.94 , AT = percentage of code that is re-engineered by automatic translation = ATPROD = Automatic translation productivity = B Scaling base-exponent that can be calibrated, currently set to= 0.91 E Scaling exponent described formula above EM 17 Effort Multipliers PM Person-Months effort from developing new and adapted code PMAuto Person-Months effort from automatic translation activities SF 5 Scale Factors

Final COCOMO -2 value is = PM =1.842

17 HMI

17.1 Alarm Alerts



Safe,Yellow and Red Alarm Representation

18 GitHub LINK

https://github.com/indomitableSameer/KMS.git