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Intelligent Equipment Health Monitoring System for Improving Availability of Remote Mining Equipment

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ABSTRACT

In today's era of competition the efforts are being made globally to reduce the mining production cost, one way to improve the mine productivity is to improve availability and Utilization of the mining Equipment by introducing a condition based preventive maintenance system. Real time monitoring system provides a cost effective mechanism to collect information from various sensors and measure the performance of the equipment which presently is taken care of by manual methods. Most of the Excavationma chinery in the underdeveloped countries is still operating without any monitoring system, as it is impossible to replace the machinery due to its high procurement cost. The sensors installed at different locations measure physical parameters such as pressure, temperature, oil levels and vibrations. Data acquired can be used to check if the acquired signal level is above or below the set values so that desired action is taken to avoid major breakdown of the equipment. Primary importance of sending the monitored data to the remote central computer with the help of network communication technology is that the timely action is taken by the managers and technicians to remove the faults to reduce downtime and improve Equipment Performance.

Keywords: Microcontroller, GSM Module, Sensors, Analog to Digital Converter, Fault Tree.

I. INTRODUCTION

It is observed that the maintenance cost of the mining equipment like Shovel and Dumper that work in poor and hazard conditions is around 35% to 50% of the total operating cost of the system [2] .The increase in automation with increase in the size and capacity of the equipment over the years has all caused concern over the ineffectiveness of the equipment. To stay competitive, mines are continuously pushing hard to increase productivity and reduce costs per ton of material moved. One way to improve productivity is to utilize equipment as effectively as possible. A low cost fault monitoring and diagnostic system has been developed to give a new lease of life to old shovels which are unable to perform due to poor feedback and with no equipment health monitoring. In addition to improved performance and availability, the mine enjoys reduced maintenance cost. The microcontroller with the help of software program checks the acquired signals with set values and issues alerts for the faults and the faulty stage. Maintenance personals can therefore take suitable action in time before the permanent failure of equipment, to improve performance and availability. The condition monitoring technology because of the various tools available has benefited to detect the fault before it happen [1]. These smart tools have the capability to handle the performance, decision making, alarm/ event handling and troubleshooting [6]-[7]. It is therefore possible to monitor the vital data for mining equipment health and safety of the workers.

II. Monitoring System Hardware

The hardware of the monitoring system mainly consist of sensors, signal conditioning circuits, analog multiplexer, Analog to Digital converter, Microcontroller and GSM module. The block diagram for acquisition of physical parameters of the mining shovel is shown in fig.1.

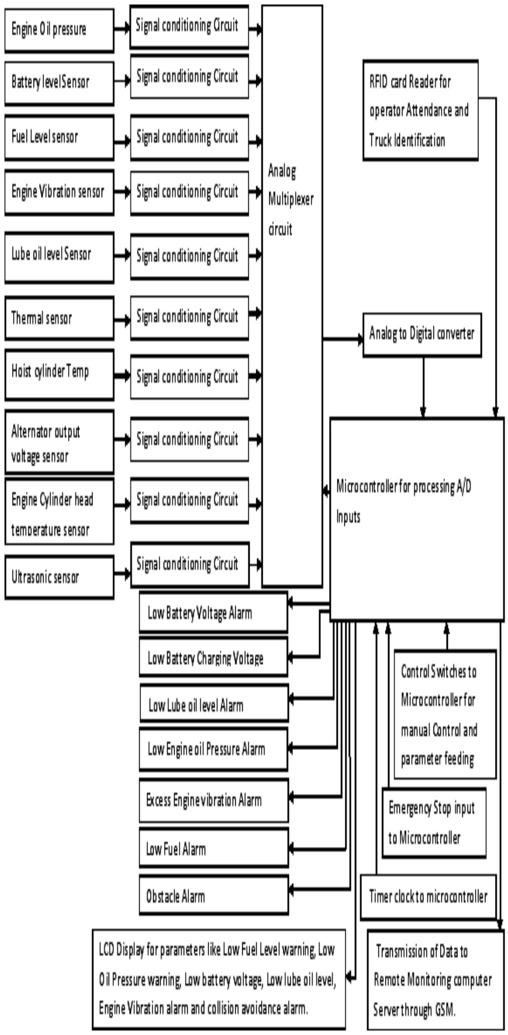

Fig.1 Data Acquisition system block diagram

2.1 Electronic Sensors

Engine Oil pressure level is checked with the help of Pressure Mems as sensor (F5) and is connected at pin no 4 mentioned as AN2, if the pressure level is low, operator can infer that the main cause of low oil pressure is due to non-operation of oil pump and engine can seize due to overheat in chamber. Hoist cylinder pressure is checked with the help of Pressure Mems as sensor (F1) to check if the pressure level is below the prescribed value, as lower limit will result into problem in the lift mechanism of the Bucket. Similarly the Hydraulic oil pressure sensor F4 gives indication if the Low Hydraulic oil level is due to broken Hose or leaking cylinder seal or damaged hydraulic pump. For vibrations sensing an accelerometer ADXL 105 is used to issue alerts to the operator if any mechanical assembly gets loose due to usage for long operating hours this can save the mining equipment from major breakdown and avoids accidents. For fuel level sensing resistive sensor is used to tell the operator that the fuel oil level has gone down the prescribed limits and refilling is desired. An alert can avoid wastage of time of the shovel and thus avoid production loss. Ultrasonic sensor is used to alert the operator if the dumper truck exceeds the set limit and come close to shovel and thus avoid accidents and safety of the driver. Thermal Sensor is used to pre warn the technicians if some circuit ambient temperature increase is detected on any electronic card, and the card is replaced before the failure of shovel machine. Inverter battery voltage level is checked so that various electronic circuits and the drive cards get the proper supply for operation of various motors in the shovel. Thermistor as sensor (F2) is used to issue alert if the Engine coolant temperature is above the set limits and maintenance personals can check if the Engine oil level is low due to some leakage or there is improper circulation of cooling fluid. All the variation in set limit is communicated to the remote supervisors through messages using GSM module SIMCON300 connected at Tx and Rx pin number 25 and 26 of the microcontroller. Actual specification for the sensors will depend upon the equipment. A prototype model of the system has been tested.

2.2 Signal Acquisition Module

The signal conditioning module and monitoring system as shown in Fig.1 mainly consists of filter circuits for filtering any noise present in the signal and amplifier to boost the signal to desired level. A 16 channels Analog multiplexer ADG 506A is used that accept many inputs but gives only single output works on +10.8V to 16.5V power supply. The availability of the output signal depends upon the selection bits issued by the microcontroller on select lines to the multiplexer at sampling frequency. The signal is converted from analog form to digital form using 16 bit AD976 for use by the microcontroller to process the signal. This ADC requires +5V Supply for operations. A PIC microcontroller (PIC18f46k22) is used for sensing, monitoring and control. The Microcontroller checks the acquired signal with the set values and issues the warning /alert messages to shovel operator on the LCD screen and also with the help of Buzzer [8], [9]. The LCD display show message for Low fuel level, Low oil Pressure warning, low Alternator output. Low battery level, Low lube oil etc. GSM technology is wireless technology and best suited for remote applications, Fiber optic technology has the drawback that it can break due to movement of trucks.

Condition monitoring [1] technology makes use of microcontroller to acquire signals from various sensors installed on the equipment to determine equipment present condition and predict the failure chances. Condition monitoring [10] [13] helps to improve equipment availability with the help various notifications as messages in the form of alarms to the operator and the maintenance personals. The immediate attention of the servicing personals helps to maximize component life and thus improves the equipment performance. Fault tree [13] concept has been used as mentioned below to help detect the faulty stage and to further narrow down the defect to a specific component.

Table 1.Shovel Mechanical Fault Analysis

S. No	**Parameter Monitored.**	**Possible cause and Faulty stage.**	Fault Message to Maintenance Department
a.	Battery Charging voltage low.	Slipping or worn alternator belts or defective alternator.	DA
b.	Battery Charging voltage high.	Defective regulator in alternator.	DAR
c.	Engine difficult to start.	Empty fuel tank or cylinder head gasket leaking or faulty fuel pump.	FFP
d.	Cylinder head temperature high	Low engine oil level due to leakage ordirt on transmission or hydraulic coolers or improper circulation of cooling Liquid.	LEOICL
e.	Dump hoist pressure low.	Low hydraulic oil level due to broken hose or leaking cylinder seals.	LCS
f.	Engine difficult to start.	Empty fuel tank or cylinder head gasket leaking or faultyfuel pump.	FFP
g.	Engine Fuming.	Leakage in transmission or hydraulic oil cooler or overloading or Improper engine valve opening.	IEVP
h.	Lack of Engine power.	Air leakage in fuel suction line, defective Injector pump nozzle.	DIPN
i.	Excess Engine noise.	Broken engine mounts or restricted air supply.	BEM
j.	Excess Engine oil consumption.	Engine oil leakage due to worn piston rings or leaking filters.	EWPR
k.	Lack of dump power.	Low hydraulic oil level due to broken hose, leaking cylinder seals or worn hydraulic pump.	WHP
l.	Hydraulic pump noisy.	Low oil level or damaged pump.	WHP
m.	Breaks slowto apply.	Foot control valve Jamming.	FCJ
n.	Engine not starting.	Electrical problem due to low battery voltage or switches faulty or starter motor struck up.	BVSMS
o.	No Electricity to lights.	Damaged wiring or circuit breaker tipped due to excess Load.	CBT
p.	Crowd motor Noisy.	Broken crowd motor mounts.	CMM
q.	Excess heat on drive circuit.	Fault in Electronic Drive card.	FEDC
r.	Engine oil pressure low.	Damaged oil Pump, Low Engine oil level due to oil leakage or worn piston rings or fuel injector pump leaking.	DPPR

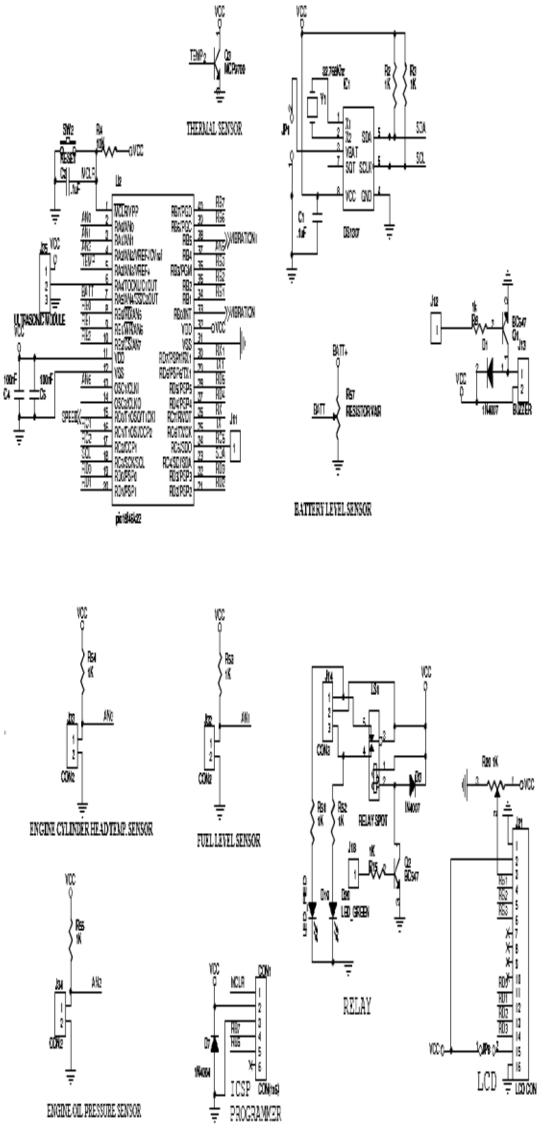

Fig 2. Microcontroller interfacing with sensors.

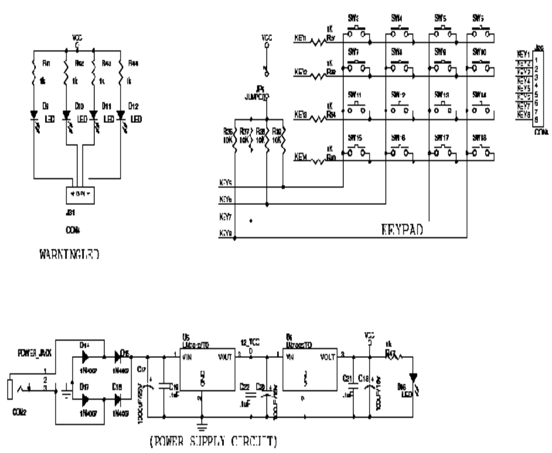

Fig 3. Power Supply Section, Warning LED's and Keyboard Section

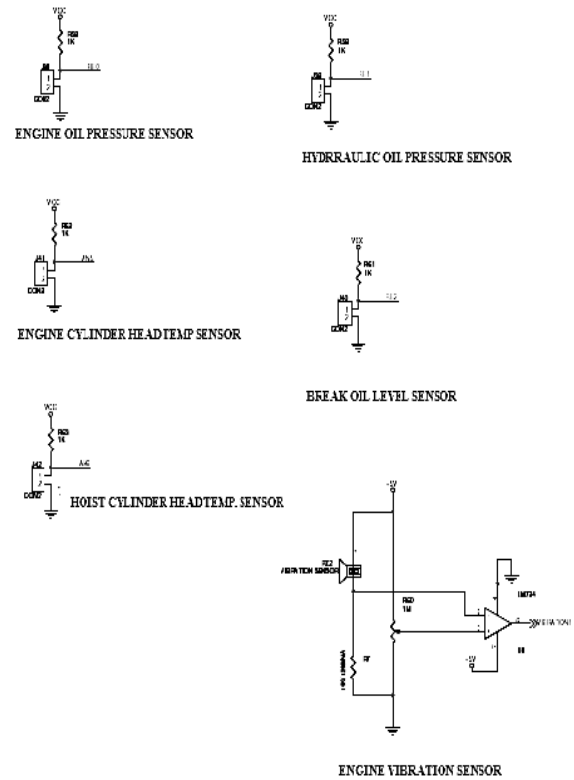

Fig 4. Sensors Interfacing

2.3 System Software

The following concept has been used for software development. The electronic Sensors acquire the data from the different sensors installed all through the equipment. The information from various sensors is checked using Logical AND, OR, NOR Gates [13] to detect the fault and the faulty state. The software compares the acquired data with the preset values using conditional statements and then issues the Alarm to the operator by ringing of the buzzer and also display the data on the operator Console. Any abnormality due to change in operating condition is also sent to the Supervisory maintenance staff with the help of GSM module Simcon300 interfaced with the Microcontroller in the form of SMS. The maintenance staff immediately knows the severity of the problem and the faulty stage and takes with them the required mechanical or electronic tools to rectify the Fault and set the equipment in the working order. These faults were previously known to the supervisors only at the end of the shift or when the equipment went out of order. Fault location time is considerably reduced to condition based preventive maintenance system, previously lot of time even many shifts were wasted due to no skill and capability of the servicing personal in locating the fault. The conditional based monitoring and communication technology has therefore helped rectify the fault immediately and has therefore helped improving the availability, and better productivity of the mine. Inspection of the equipment that was carried out

Table 2. Availability with and without Monitoring System

Days	Down time in Hrs due to various Electromechanical Faults (F1-F6)						Down Time(Hrs)		%Availability	
	F1	F2	F3	F4	F5	F6	Without Monitoring	With Monitoring	Without Monitoring	With Monitor
1-7	96	48	0	0	0	0	144	80	14	52.38
8-15	149	0	14	0	0	0	163	72	2.9	57
16-23	0	0	9	14	0	2	25	18	85	89
24-30	2	0	0	32	32	0	66	40	60.7	76

manually previously has been replaced with intelligent automated system and therefore helps the operator to take preventive actions to avoid the equipment for major breakdowns. Information from the various hardware sensors for any change in Parameter is directly available to the operator on the screen and also communicated to the maintenance department for early action.

Software for checking the different mechanical faults [13] is based on the following Conditional statements as mentioned below:

1) If Engine oil_psi is low.
   Then mechanics are defective.
2) If Alternator is fail.
   Then electricity is low.
3) If battery voltages is low.
   Then electricity is low.
4) If electricity is low.
   Then drives are unable to work.
5) If oil _level is low.
   Then hydraulic pumps can be faulty.
6) If hydraulic pumps are unable to work.
   Then hydraulics is defective.
7) If cylinder head temperature is high.
   Then engine oil level may be low.
8) If dump hoist pressure is low.
   Then hydraulic oil level is possibly low
   Due to defective hose or leaking seal.
9) If charging voltage is low.
   Then alternator is defective.
10) If Battery charging voltage is high.
   T hen regulator in alternator is defective.
11) If Engine is difficult to start.
   Then fuel tank can be empty or cylinder
   Head gasket leaking or faulty fuel pump.
12) If engine noise is excessive.
   Then engine mounts may be broken or
   Restricted air supply.
13) If engine oil level is low (high consumption)
   Then piston rings may be damaged.
14) If hoist cylinder temp is high. Then hoist holding power is low.

Maintenance, Breakdown and Idle condition data for the month of April 2013 of DEMAG H55 Mining Shovel operating in the Eastern Coal fields at Gopinath Pura Dhanbad Open cast mine has been used for analysis as shown in table 2.

III. Fault & Availability Analysis

F1-Hoist cylinder Pressure low, F2-Engine Cylinder head Temperature High, F3-Hour Meter Fault, F4-Hydraulic Oil Pressure Low, F5-Engine Oil pressure Low, F6-Low Battery output Voltage.

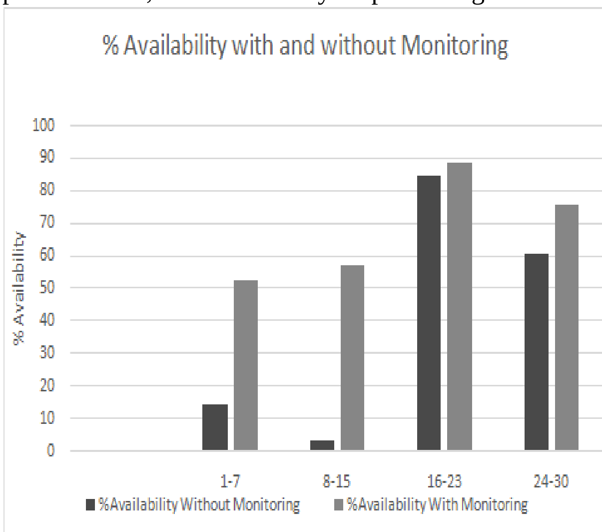

Fig 5: Availability Chart

Availability of the equipment is mainly affected by the down time, this factor indicates that the equipment is in working state and can be used for the intended purpose [4].

Total Hours
= (Total Hours –Downtime Hours)*100%

Total operating time (hrs) for one month's period
=1*30*24=720hrs
Down time hours without monitoring
=144+163+25+66
=398hrs.
Availability without monitoring system
= (720-398)/720
=44.7%
Down time hours with monitoring
=80+72+18+40
=210hrs.
Availability with monitoring system
= (720-210)/720)* 100
= 70.8%

As the repair time to bring the mining shovel back into working state mainly depends upon the maintenance skill and capability of maintenance personnel's, there is expected average improvement of 26% in Availability of Mining shovel from 45% to 70.8% with Equipment Health Monitoring System as shown in Fig 5. The international standards have suggested that the Availability of mining equipment should be above 85%. Availability and Utilization of the equipment indicates that that achieving high equipment availability is a Maintenance responsibility and while achieving high utilization is a production responsibility, therefore if equipment utilization and availability are maintained high, maximum productivity can be achieved from the mining Equipment.

IV. System Benefits

The proposed system therefore helps monitor the physical parameters and helps the operator and the servicing personnel's to immediately know the equipment healthy state for operations, as he gets the information from the various sensors immediately on startup. The time for detection of fault and the faulty stage is drastically reduced from days to few hours. The part procurement time due to instant information in the form of messages to the servicing department and the purchase Managers also helps bringing the equipment to the up state at the earliest. Therefore there is an inherent benefit in case of monitoring system, that the mining workforce take with them the necessary tools and the part to be repaired or replaced in the shovel immediately on receipt of message and thus helps minimizing the down state. Previously these Parameters were monitored manually and therefore standby time is reduced considerably. Since the equipment failures are addressed properly by preventing major Failures and have therefore resulted into improving the equipment life. Due to shifting of unscheduled downtime to Scheduled downtime, operational impact is minimized and production goals can be easily achieved. Most of the Excavating machinery in the open cast mines in the underdeveloped countries is still operating without any monitoring system, as it is impossible to replace the machinery due to its high procurement cost, the proposed can be fitted in the old shovels at fractional cost to improve their availability and utilization to achieve the desired production goals.

REFERENCES

[1] Ni News,"Increasing Equipment Uptime and Reliability with Condition Monitoring", National Instruments, Sept, 2011, from http://www.ni.com/newsletter/51426/en/.
[2] Bin Guang-fu, Li Xue-Jun,Balbir S Dhillon, Huang Zhen-Yu, GuoDengta, "The integrated monitoring system for running parameters of key mining Equipment based on condition monitoring technology", China Journal of coal science & Engineering, 2010, 16 (1), 108-112.
[3] John Chadwick, "The Autonomous mine", The international mining magazine, 2010, 46-57.
[4] Sermin Elevli ,Birol Elevli, "Performance Measurement of Mining Equipments by Utilizing OEE", ACTA Montanistica Slovaca, 15 (2), 2010, 95-101.
[5] Li X J,Qiu W L, Chu F L, "Remote monitoring and control system for key Equipment in coal-mine based on signal acquisition and data analysis". China Journal of scientific instrument, 2009, 126-133.
[6] Shi Wei, Li Li-li, "Multi-Parameters monitoring system for coal mine based on wireless sensor network technology", China International Conference on Industrial Mechatronics and Automation, 2009, 225-227.
[7] Zhichang ,Zhangeng Sun and Junbao Gu, "Study on the technology of the Coal Mining Safety monitoring system," China Journal of Applied science, 3 (8), 2009, 95-99.
[8] Heyes A. L, Feist J P, Chen X,MutasimZ,Nicholls J R, "Optical Nondestructive condition monitoring of thermal barrier coatings," Journal of

Engineering for gas turbines and power, 130 (6), 2008, 1- 9.

[9] R. L Himte, A. PKedar, P. V Washimkar, M. V Wakhare and P. N Belkhode, "An Approach to Improve the Productivity of Dumper by Preventive Maintenance", International Conference on Emerging trends in Engineering and Technology, 2008, 735-738.

[10] Werner J, Lewis M W, "The integration of condition monitoring into the maintenance process", CIM/ICM Bulletin technical papers, 124, 163-168, 2006.

[11] Zhang W M, ''Configuration software control technology", Beijing, **B**eijing Jiaotong University Press, 2006.

[12] M.D Kuruppu, "New technologies available to maximizing equipment reliability", Taylor Francis group London, 2004.

[13] A Ursenbach, Qun Wang and Ming Rao, ''Intelligent Maintenance support System for mining truck conditioning monitoring andtroubleshooting", International journal of surface mining, Mining Reclamation and environment, 8 (1), 1994, 73-81.