Industrial Automation and Control System to Minimize Food Spoilage and Imports in Pakistan

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***Abstract*—Food spoilage and subsequent imports can be reduced by modernization of storage and warehousing facilities through industrial automation and remote control systems. A home grown solution to industrial automation that is cost, energy, and resource efficient with standard automation, control and communication features has been developed and presented in this paper. Experimental results reveal the scalability, objectivity, accuracy, stability, economy and ease of deployment of developed system.**

I. Introduction

Industrial automation utilizes sensors, embedded design, control systems and information technology to reduce the need for human intervention. In the scope of industrialization, automation is a step beyond mechanization. Whereas mechanization provided human operators with machinery to assist them with the physical requirements of work, automation greatly reduces the need for human sensory and mental requirements. Most of the world automated their industries knowing the fact that mass production is no longer efficient at hourly worker rates, which completely changed the way of getting information, information analysis, decision and action selection and the action implementation but unlike the rest of the world Pakistan is far behind in industrial automation.

Storages and Warehouses are very important part of Industry. As they are the source for providing Raw material to major industries by storing and preserving for long time. Pakistan is one of the largest producers of major corps, fruits and vegetables in the world as shown in the table 1. But instead of having excess like other agricultural countries we mostly have shortages because most of the corps and fruits produced here are not properly utilized and hence wasted or exported due to lack of proper storage facilities. So we need to have proper and efficient storage capacity for storing our excess produce.

A storage facility should maintain the proper environmental conditions of the stored Product. For instance to store fruits, low temperature and high humidity ranges are required while pulses and potatoes require low humidity levels. Hence in order to maintain quality, improve their shelf life and extend marketing period of fruits and vegetables, the control of environment conditions during storage and transportations are very much important.[1][2]

For storage of food items in a cold storage various measurements are required to record the temperature, humidity and other factors in different parts of the large cold store to make the automation work effectively. Accurate measurement of temperature with high resolution and stability at low temperature for fresh saving is a big problem in a cold storage thus a temperature sensor having high resolution and stability is desirable.

The conventional monitoring system is very expensive and complex. In conventional cold storage the temperature adjustment and storage method depends upon the experience of the expert operator. This creates the problem that an operator/ assistant should always stay at the cold storage to adjust the temperature and manage the system by periodic measurements [3]. There is always a factor of negligence and inaccuracy due to human intervention and a slight negligence can cost the perishing of the whole stored product. This issue can be resolved through automation. The major attributes of desired automation and control system are listed below:

- Automation system is required to control the storage environment and to perform decision automatically for the preset values so no need an operator to always stay at the storage.
- To ensure a controlled environment, the proposed automation system is required to measure temperature accurately with high resolution. A higher measured resolution would provide more time for initiating an accurate and appropriate response. For example, potatoes are to be stored within temperature range of 0-2^0C. Recession of temperature below 0^0C would blacken potatoes and exposure to temperatures above 2^0C would increase starch production is stored potatoes resulting in depreciation in net worth of stored produce.
- Automation can reduce the role of operator to just check whether the system is working correctly and the system has provision of remote monitoring through wireless network.
- Providing remote access is also a key feature of the project as it provides the user with the freedom to control the system from any place instead of remaining at the site all the time. For this purpose central controller sends the data to remote user using existing wireless mobile infrastructure.
- Power consumption and continuous power supply is also a factor in stability of the system. So less power consumption and automatically operated generators can be an important feature of the automated system. Less power consumption can be achieved by having throw away sensors and their monitoring by a central

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controller instead of having multiple sensors and measuring their temperature separately.

There are some existing solutions to this problem but 1) they are not fully automated as most of them require an operator to make decision on the calculated value. 2) They also lack sending of data through long distance due to their designs. 3) their sensing and decision making accuracy is also less. And 4) they are also too expensive for a local buyer.

TABLE I: AGRICULTURAL OUTPUT OF PAKISTAN 2009-10[4]

Sr. No	Commodity	World Production rank
1	Chick-Peas	2
2	Okra	3
3	Apricots	4
4	Mangoes	4
5	Dates	5
6	Onions, Dry	5
7	Sugar Cane	5
8	Fruit Tropical	7
9	Cauliflower	8
10	Wheat	9
11	Pistachios	10
12	Oranges	12
13	Peas, Green	14

The economic situation of Pakistan demands a cheap and accurate automation system which everyone can easily afford. The only way to achieve minimum cost is to develop a home grown solution.

After looking into matter and to overcome the problem, the system we have designed for the automation of cold storages is cheap, accurate, power efficient and scalable with automatically operated alarms, chillers and generators when required. Instead of automated decisions, functions of system can be controlled by a remote authorized user using remote access. Below are previous development and our further work on the automation of cold storages.

II. RELATED WORK

The Rinnovando group [5] has studied tomato greenhouses in the South of Italy with Sensicast devices for measuring the air temperature, relativity humidity and soil temperature measurements with wireless sensor network. They have also developed a Web-based plant monitoring application. Greenhouse grower can read the measurements over the Internet, and an alarm will be sent to his mobile phone by SMS or GPRS if some measurement variable changes rapidly. Bridge node gathers data from other sensor nodes, which transmit the measurements of temperature and relative humidity in one minute intervals [5] .

Mohsin et. al. [6] have researched automation of poultry farms in Pakistan with wireless sensors based on Crossbow's TelosB Mote TRP2420 and temperature and humidity sensor sht111, which measures temperature with accuracy ±0.3 and humidity with accuracy ±2%. Multiple sensor are deployed and temperature and humidity from every sensor is measured after 10 minutes. Due to wireless network their indoor communication distance with tolerable packet loss is 40 meters. These results are then stored in a computer program and decision is performed by the operator on the computer [6].

Lim et. al. [3] worked on the automation of the cold storage. They developed a remote monitoring system using serial communication. The system is useful for managing a cold-storage. The composition of the system includes a cold-storage, a freezing unit, a temperature controller, a data collection device, a communication device, and monitoring program. In their system the computer programs collets the data and an operator is required to monitor computer program and to make decisions [3]

Freitas et. al. [7] proposed a system for monitoring and control of a cooling system in a commercial store based on PLC's. Their system collects data through computer program and makes action according to needs. Their system generates GSM alert to the operator. Operator will perform the action required. They worked more on software design for collecting temperature data showing its graphical and average values and generating reports for the authorities [7].

III. COLD STORAGE AUTOMATION AND REMOTE ACCESS

In a cold storage environment it is essential to maintain specific temperature and humidity so that condition of the product is preserved. Every product has different suitable temperature ranges under which they can be stored and there freshness can be maintained.

Temperature and humidity are closely linked together in a controlled environment. Cold air has a lower moisture-holding capacity than warmer air, and therefore the decrease of the relative humidity is a sign of increased air temperature.[8]

Taking in account all the previous work we have developed a cold storage automation system having all the mentioned features with minimal cost, power saving, removing human error and providing remote access.

We can divide the automation of cold storage into some major task: temperature/humidity measurement, comparison with preset values, performing of the required action automatically and remote monitoring. To measure the temperature number of temperature sensors are interfaced with the central controller, which gathers the data sent to it by all the sensors, compare the data with the preset values and perform the required actions. The accuracy level of the developed temperature sensor is $\pm 0.06^0$C.

We used throw away sensors. So there are not any fixed number of sensor per storage you can have any number of sensors in a store. Sensors are connected to central controller using wired topology to enhance the date transmission ranges instead of using wireless for short ranges of transmission and higher power consumption.

Cold storages have very high ceilings and inside temperature varies with height the sensors are placed at different heights for an accurate average temperature value. User-Machine interface is also provided on the central controller. User can set the upper and lower ranges of the temperature for alarms and notification and the automated

decision is performed according to these values. All the control/decisions signals are fed to relays so when temperature of the storage reaches the upper range then air conditioning or chilling of the storage automatically starts and remains on till the temperature reaches the lower limit. And similarly a humidity sensor is connected to the exhaust and sprinklers so whenever humidity is increased by a certain level the exhaust automatically turned ON and conversely sprinklers would be activated to increase humidity. Whenever there is a power failure, the central controller will turn on the generator according to its need.

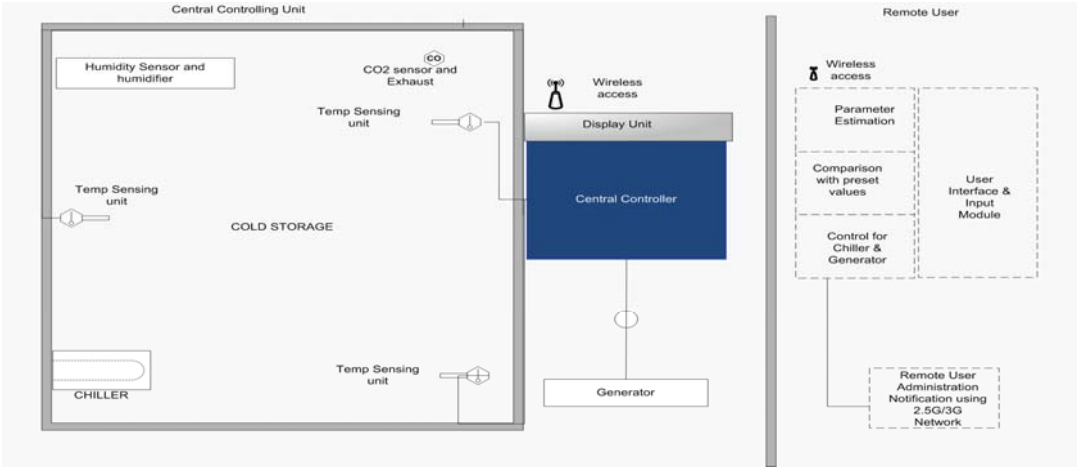

Fig. 1. System design

An operating system provided on the central controller supports display of the temperature of all sensors and upper and lower limits of temperature for the cold storage all the time. The whole controlled system is working on low power levels. The automation system only requires 5V-12V voltage and very less current. So there is no extra need of a UPS system installed for the stability of the system. Stability can be achieved by a simple 12V battery.

Remote access is also provided to the administrator using wireless technology. The central controller sends its measured data to any remote authenticated user. That authenticated user can change the parameter of the decisions also like upper and lower limits of temperature. Remote user can perform any required action himself bypassing the automated decision function of the central controller.

The system is built taking in account the economic view. So the most accurate, less power consuming and low cost sensors and other devices are used to ensure the cost of whole system remains very low.

A. Temperature Sensor

The temperature sensor we used is DS1820.It's resolution is 9 bit and its default accuracy is $\pm 0.5^0$C. And the temperature range is -55^0C to 125^0C. The accuracy of DS1820 can be increased up to 0.06^0C using the following formula:[9]

Temperature=temp_read - 0.25+(COUNT_PER_C – COUNT_REMAIN)/(COUNT_PER_C).

First, read the temperature, and truncate the 0.5°C bit (the LSB) from the read value. This value is TEMP_READ. COUNT_PER_C and COUNT_REMAIN are the registers of the scratchpad of DS1820.(Datasheet Ds1820) The fabricator of DS1820 makes a constant value of 10h of COUNT_PER_C but the values of COUNT_REMAIN changes with the changing of temperature.

We are using One Wire system so we have its characteristics like: Single master system, low cost, low transfer rates (up to 16 kbps), fairly long distances (up to 300 meters) and small data transfer

Packages. For accurate temperature measurement we will take average value of all the sensors present and these stats would be collected periodically after every second.

B. Central Controller

The most important part of the system is a central controller. It consists of a microprocessor, display unit (LCD), User-Machine interface (keypad), relays, wireless data transfer capability for remote access & alarms. The main function of the central controller is to obtain the temperature from all the sensors, averaged the obtained temperature, and then compares it with presets and performing of decision accordingly. Decisions of central controller will be turning ON & OFF the air conditioning unit, turning on the generators in case of power failures and turning the alarm ON during critical case.

User-Machine interface is also provided on the central controller. User can set temperature limits and browse through data of different sensors according to his requirements. The user-machine interface used is a keypad. A display unit (LCD) is also provided on the central controller displaying all the temperatures measurements and functions performed by the user interface.

To provide remote access to administrators' wireless capability is also installed at the central controller. Function of the remote access is to authenticate the user and provide it with the required data/alerts. To provide wireless capability GSM (2.5G) System is installed at both the central controller and at the remote user.

C. Humidity Sensor

The relative humidity in refrigerated storage must be within the optimum range for the commodity. For most fruits and vegetables, the optimum relative humidity is 90–95 percent. When relative humidity inside the refrigerated storage is less than 90 percent, the facility should use a humidifier [10]. Therefore a humidity sensor is placed inside

the cold storage and it is connected to the humidifier of the storage. So when ever humidity level falls below 90percent the humidifier will turn ON automatically.

D. Remote Access

Remote access is provided to give administrator the freedom to not get fixed to a fixed location they can check the system on the go. The remote access device consists of wireless module, user interface and microcontroller. The central controller sends all the alarm alerts and automated actions taken to the remote user using wireless medium, user can proceed with the automatic action or take some action himself. Using Man-Machine interface user can interact with the system and can be able to set/change temperature alarm limit or can bypass automatic decision process of the central controller and can turn on Chillers/Generators himself.

IV. Results

Following table shows some of achievements of our product.

TABLE II: Results & Comparisons

Features	**Values**
Temperature Step Size	0.0625^{o}C
Temp. Data transmission range using wired medium	Greater than 250meters
Time for measuring temperature of a single sensor	1 Second.
Total No. of cold storages in Pakistan	533[2]
Min. Power saved per storage due to automation	10-15 kWh per day(minimum)
Total power saved if all storages in Punjab, Pakistan are automated	i)5330-7995 kWh per day ii)1945450-2918175 kWh per year
Average cost of commercially available systems	25,000 – 30,000$
Total cost of our developed system	350 - 400$

As from table the temperature step size is 0.0625^{0}C so we will have more instances to perform decisions and this will contribute in saving power. The reliable temperature transmission range is greater than 250 meters so size of the store doesn't matter our system can easily manage large stores. As system is précised so power can be saved and an average of 10-15 units per day per cold storage are saved. And all of us know that power is the major crisis in Pakistan these days so we can save up to 2MW to 3MW of power per year if all the storages are automated which is quite an achievement. There are already some cold storage automation systems available in market but they are not installed in our country because they are too expensive. So taking in account this problem we have reduced to cost of the system to a great extent.

V. Conclusion

An accurate, reliable and low cost industrial automation system with remote monitoring and control features has been presented in this paper. The system is intended to reduce food spoilage and shortages and is found to conserve power as well. The communication among sensors has been found to be reliable and rate of error is minimal as wired communication is used to transfer data from sensors to central control unit. In future, we wish to introduce wireless communication among sensors and include better, energy efficient, non round based communication protocols.

References

[1] K. Zhang and J. Liu, Study on Human-simulated Intelligent Control Method of Fruit &Vegetable Cold Storage, 2009.

[2] *Pre. Feasibility Study on Cold Storage by SMEDA (Small and Medium Enterprise development Authority)*, present at Government of Pakistan, Feb 2009.

[3] D. Y. Lim, Y. J. Ryoo, J. Y. Gwark, Y. H. Chan g, and C. J. Moon, "Remote Monitoring System for Cold-Storage Using Serial Communication," ICCAS2003 Gyeongju TEMF Hotel, Gyeongju, Korea.

[4] United Nation Rankings for World Food Production. [Online]. Available: http://www.fao.org/es/ess/top/topproduction.html?lang=en&country=165&year=2005.

[5] M. Mancuso and F. Bustaffa, "A Wireless Sensors Network for Monitoring Environmental Variables in a Tomato Greenhouse," in *Proc. of 6th IEEE International Workshop on Factory Communication Systems*, Torino Italy, June 28-30, 2006.

[6] M. Murad, K. M. Yahya, G. M. Hassan, "Web Based Poultry Farm Monitoring system using wireless sensors," in *Proc. International Conference on Frontiers of IT in Comsats Institute of IT Abbotabad*, 2009.

[7] R. Freitas, F. Soares, V. Vieira, J. Machado," Monitoring and Control of a Cooling System in a Commercial Store," *The world congress on engineering*, vol. II, June 30-July 2 2010, London, UK.

[8] Temperature and humidity perception. [Online]. Available: http://www.newton.dep.anl.gov/askasci/wea00/wea00133.htm

[9] *Pre-Feasibility Study Establishment of Cold Chain System Under National Trade Corridor Improvement Project*, vol. 3, 2007.