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Proposal of a Cost-Saving and Risk Prevention Mechatronic System for Water Consumption Systems of Buildings

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This study aims to develop an integrated control system to prevent the indoor loss of water. In general, these losses occur while using the hot water, because of forgetting to close the water batteries during the water cuts, or due to faults in washing machines, dishwashers and indoor plumbing systems. In this study, a specialized solution is developed for each type of losses. Then, the developed three subsystems were combined and transformed into an integrated system. This study shows that water losses in the housing can be prevented by using advanced technologies. There are similar systems in practice, but this study is different from the others with regard to its holistic approach, addressing all three problems together. The contribution of the system to economic and social life will be great, when water saving and environmental damage are considered.

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1. Introduction

Water is one of the most important natural resources and has to be saved. Today, saving measures are taken to use water efficiently. On the other hand, smart home systems have been developed and presented to human use. Addition of technology to the comfort and security has become a symbol of social status. In this context, many researchers have focused their work on smart home technologies.

Al-Ali et al. have studied the design, implementation and testing of an embedded system that integrates solar and storage energy resources in a smart home. The study provides and manages a smart home energy requirement by installing renewable energy sources [1].

In another study, Darianian and Michael have introduced a smart home service system, that benefits in terms of cost, energy consumption and complexity. This system can be used for washing programs, cooking, shopping and elderly health care [2].

A smart home device has been designed by Han and Lim. The device has been used for the smart energy applications of residential or light commercial environment [3].

Honda has designed a smart home with very low water consumption. It was expect to have a slightly lower consumption than the industry best practice. But, in fact, for the first six months of data monitoring, the developed system has reduced water consumption by 40% [4].

Jahn, et al. have designed a novel smart home system, integrating energy efficiency features. They have interconnected common devices available in private households and integrated wireless power metering plugs to gain access to energy consumption data [5].

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The design of a smart home system based on Internet of things (IOT) has been presented by Li and Yu. The system can help to realize every changing dynamic semantic integration of the web services. They have also explained the software architecture and main modules of the system [6].

However, most of these studies are concerned with energy management and comfort. There are less studies on saving and productivity. However today, for peace and happiness of the humanity, the “human-centered design and engineering" approach stands out. Therefore, in recent years, there are important initiatives in order to ensure more efficient use of water and to avoid unnecessary use.

Almandoz et al. have stduied the leakage assessment through water distribution network simulation. The methodology used in the simulation has evaluated water losses based on discrimination of the two components of uncontrolled water in a water distribution network. These physical losses arise in mains and service connections [7].

The risk assessment and modelling for small scale water recycling system have been studied by Diaper et al. They have used quantitative risk analysis, risk modelling and simulation modelling tools to assess the performance of a proprietary single house grey water recycling system [8].

Liu et al. have investigated impacts of residence time during storage on potential of water saving for grey water recycling system. In the study, water saving efficiency (WSE) and residence time index (RTI) have been employed to reflect the system's performance and residence time during storage, respectively. The results of the study have shown that WSE and RTI change inversely proportional with the storage tank volume [9].

Kilic has studied the imbalance problem in the electric motors and the centrifugal pumps and the failures caused by the vibrations. He suggested that the problem of imbalance in the electric motors and centrifugal pumps can be easily detected by the vibration analysis method [10]. Kilic has also studied the decrease of the leakages and prevention of water loss in drinking water distribution network system in his other study [11].

Uncu and Akdurul have studied water quality of water resources via telemetric systems. They have performed a remotely-controlled dosing operation in their study [12].

It is seen from the studies in the literature that the total water consumption can be reduced by a certain degree with saving measures. However, the loss in water distribution system of buildings is also an important consumption cause. The most of these losses can be prevented by using advanced technological techniques and equipment.

Thus, aim of this study is to design a mechatronic system, which could save water and prevent potential risks. A prototype of the designed system has been realized and the system has been tested by using the prototype.

2. System design for cost-saving and risk prevention

This study aims to develop an integrated control system to prevent the indoor loss of water. In general, these losses occur while using the hot water, after forgetting to close the water batteries during the water cuts, or due to faults in washing machines, dishwashers and indoor plumbing systems.

In this study, a specialized subsystem, corresponding to each problem, is developed and applied to plumbing. Then, the three developed subsystems were combined and transformed into an integrated system. These subsystems provide prevention of losses of water below the desired water temperature, the prevention of losses caused by leaks and prevention of risks resulting from the battery kept open when the water is cut off.

2.1. Design of hot water recycling systems

The water heater begins to heat the water when the hot water tap is opened. However, the cold water in the installation between the battery and the water heater is discharged as waste for a certain time. In this case water and energy losses occur, which cause waste of water resources. In order to overcome this disadvantage, a new system has been developed in this study.

In this system, the cold water of the hot water distribution system, that comes to battery, is being re-circulated and is being passed through heating source and is made ready to use at a suitable temperature in a very short time. This system forces the water, that does not reach the desire temperature, to pass through the heater again. Circulating can be performed when water is sent to the input of the existing network, or a separate plumbing is laid. The developed system is shown in Fig. 1.

The temperature recycling system can operate in four different modes, depending on the purpose of use. These modes are continuous operation mode, timer-controlled mode, thermostat-controlled mode and button control mode. The modes depend on the input parameters, provided by the user.

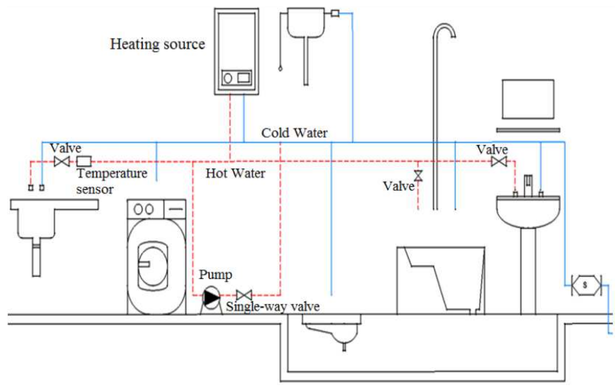

Fig. 1. The hot water recycling system.

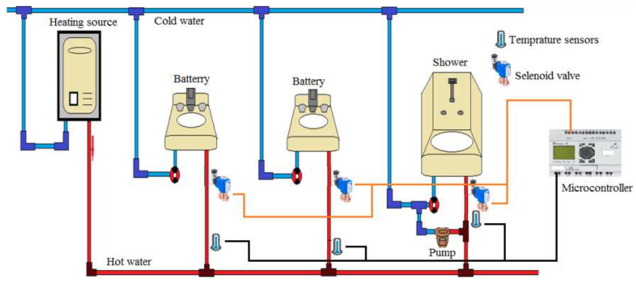

Fig. 2. Thermostat-controlled system.

The most effective of these modes is thermostat-controlled mode. Operation in this mode is as follows, the temperature of the water from the battery is measured by thermostat and the pump is started, when temperature is below the desired value. Hot water flows from the battery by closing the pump when the water temperature reaches the set value. In this mode user has to wait for hot water for a short period. The operation diagram of this system is presented in Fig. 2.

2.2. Design of flood prevention system

Another important reason of water loss is the forgotten open water batteries during the water cuts. If there is a water cut, when no one is at home, and the water tap is left open, a flooding can occur indoors, when water appears again in the line. In this case, when there is no water in plumbing, the main valve is closed by the developed system, based on readings of a pressure sensor, for detecting risky low pressure situation. When the water is turned on and the battery is disconnected,

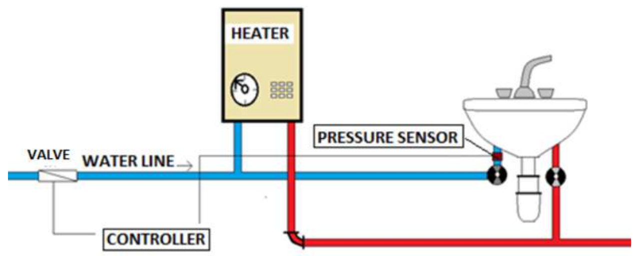

Fig. 3. Flood prevention system.

the pressure in the plumbing is measured with a pressure sensor and the obtained values are sent to the control organ. Controller compares the value from the sensor with normal networks pressure. When pressure values from the sensor are smaller than the normal mains pressure, the controller closes the main inlet valve. The schematic representation of this system is shown in Fig. 3.

2.3. Design of leakage prevention system

Another reason of water losses, commonly encountered in water supply systems, is leakage in plumbing or in a system connected to the plumbing. When the leakages are not detected, they cause big losses and material damages. Some similar systems have been developed for same purpose, however this study is different from the others with regard to its holistic approach, addressing all three problems together. Humidity sensors are placed in the potential leakage zones. When the abnormal humidity values are transmitted to the controller the main inlet valve is closed and the warning signal is activated. The scheme of the system is given in Fig. 4.

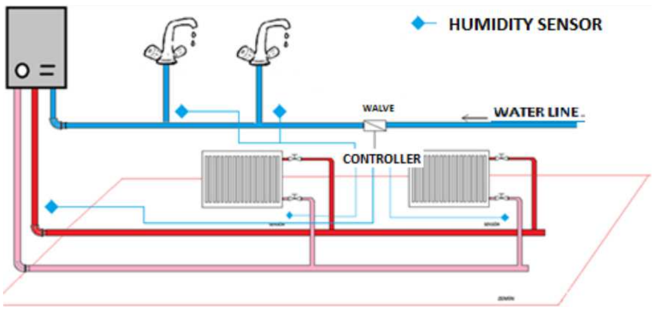

Fig. 4. Leak prevention system.

3. Integration of the systems and application

In this study, the developed subsystems for cost-saving and risk prevention are integrated into an integrated system. The hot water in the water installation has been used efficiently thanks to this integrated system. Moreover flood prevention and detection of leakage in the indoor plumbing system have been achieved. A human-machine interface has been also developed, so that the system can be controlled and managed effectively in real time. In other words, the manual and automatic control parameters of the system have been managed via a screen.

The configuration of the integrated system is possible using various algorithms for such systems. Obviously, the algorithm selection, which would provide optimal operating conditions is important. The flow diagram, which shows the operation steps of integrated system is given in Fig. 5.

A prototype of the designed integrated system has been implemented. Numerous observations have been obtained by testing the prototype. Finally, the desired results have been compared with the obtained results and thus, the operation of the system has been verified. The prototype of the integrated system is shown in Fig. 6.

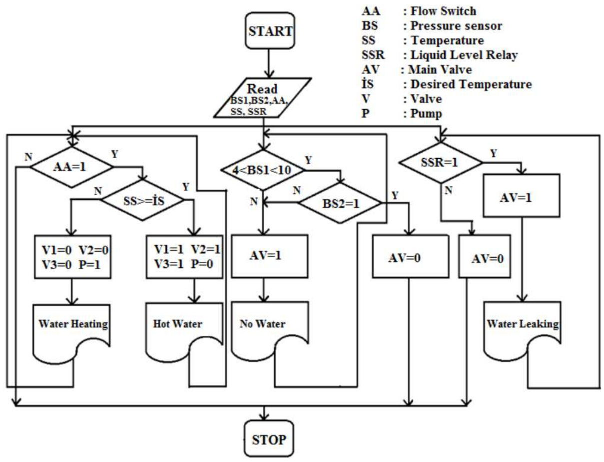

Fig. 5. The flow diagram of the system.

Fig. 6. The prototype of the integrated system.

4. Conclusions

In this study, an integrated indoor control system to prevent the loss of water and risks has been developed. A prototype of the designed integrated system has been implemented. The desired results have been compared with the obtained results and thus operation of the system has been verified. When the developed control system is used, water saving and prevention of environmental damage will be possible and so the system will contribute to economic and social life.

The conclusions, drawn from this study, can be summarized as follows:

- The system can be easily implemented in available structures and in structures under construction.
- The installation and operating costs of the system are low and it is practical for individual users.
- The contribution of the system will be great, considering water saving and environmental damage.
- The system can easily be applied to smart structures.

- The system will provide a positive contribution to employment and the economy.

This study shows that indoor water losses and potential indoor risks can be prevented by using advanced technologies.

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