Smart Water—An Automation of Existing Waste Water Filtration and Recycling System

Vrushali G. Nasre, Sudarshan Rao, Sushant Tupparwar, Disha Bhatt and Shriyash Deoghare

Abstract Clean and hygienic drinking water is a elementary requirement of human beings. Automation of water treatment plants plays a vibrant protagonist in the safe and consistent action in providing household usable water. This system emphases on an advanced, smart control & Checking system for water purification by using "IOT" And "microcontroller". This proposed system is an attempt to design a cost effective water filtration with smart control recycling system. In this system the bathroom & kitchen basin waste-water is reused for gardening, and toilet flushing. The basin water is passed through the "purifier system" Which consist of different purification techniques such as sedimentation, charcoal purifier, silica beads treatment is used so the water get purified close to neutral pH value. Water recycled is neither acidic nor alkali. The system also eliminates the undesirable color & odor of the water. For this "microcontroller system" is used to control flow of water and check turbidity of water. It is an automatic device that can provide safe, reasonable and readily available water for household usage. "IOT System" is connected to incoming water supply and check's the real time billing system and water usage. It also detects the "leakage of water". This system has "Hydro-power generator" which generates power by flow of water & stores the energy in a Lithium-Ion battery, so in case of power failure it can provide power to the recycling system for uninterruptable service.

Keywords Water · Recycling · IOT—Internet of things · Purification · Sedimentation · Microcontroller · Leakage of water · Hydro-power generator

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1 Introduction

Water-H_2O is one of the key and well known natural resource and is played vital role for entire living things on the earth planet. As more than 60% of human body is filed with water, therefore quality and cleanliness of water is very essential. Now a day, only 3% fresh water resources are available on earth. According to the survey, 124 Million liters/day of water is lost in leakage & illegal connections. Flush of a toilet uses 6.5 gallons of water daily. 70% of the world is composed of water, salt and sea. Concrete cities have caused reduction in ground water level. However, due to human consumption and irresponsibility, water pollution was inevitable thus limiting the supply of portable water. On the basis of the study, the aforementioned problems also occur in water resources.

The drinking water must be hygienic, uncontaminated, microorganisms free and germ-free before consuming it. All water treatment plants treat the raw water from Reservoirs like river, lake, dams or other underground resources and provide harmless and clean drinking water to mankind. But the same water is used in daily household uses like bathroom and toilet flushing, kitchen purpose, gardening, washing (cloths and utensils), cleaning vehicles, and other many more. And that water can be called it as waste water. Considering the rate of change of increasing population, supplying clean and hygienic water to each individual is a most essential challenge. Exponential growth in population, industrialization and urbanization leads to wastage and scarcity of water. Increasing growth rate of Population in India is indications to significant increases quantity of waste water, which makes it an urgent imperative to develop cost effective and strong modern technologies for waste water management and treatment.

Recycled water is waste water that has been purified so that it is suitable for a range of non-drinking purposes. Improper waste management causes various environmental issues such as soil erosion and contamination of fresh water bodies. Thus recycling and proper management of waste water is the need of the hour. The methodologies or techniques and the level of purification of water depend on the financial feasibility. Grey water is dumped in open area, which causes soil erosion and contamination of soil which makes land unsuitable for agriculture. Common assumption among the people is that recycled water is not appropriate for daily usage. Valves are controlled manually, so there is a chance of human error. Leakage and water theft detection is difficult.

Unconventional technologies for waste water treatment are required to eliminate pollution. Automation is essential to water treatment plant monitoring and controlling since it has various perceptible and immaterial benefits. In order to address these problems, the researchers decided to design a system that can recycle waste water from the home to provide clean water and serves for conserving water for the next generation. The proposed system describes a modern technology that can automatically recycle the waste water coming from the outlet of the home except flushed water of the toilet, which will be useful for gardening, toilet flushing.

2 Existing Methods

2.1 For Water Purification

One of the existing methods for water purification is the ultraviolet water treatment process. UV rays decontaminate the water without adding any impurities like unwanted color, scent, chemicals or taste and there are no residual any products. UV treatment is one of the fastest and very cost effective and environment friendly process. UV technology is easy method for this kind of application since it provides immediate results without any by-products they leave behind. The size of the UV equipment is very small so device is easy to handle. The major drawback of UV treatment is it completely destroys the residual ozone present in a water stream. This process is depends on the flow rate of water, absorption of ozone in water, feed water quality and the temperature of the water stream and surrounding temperature. Investment cost depends on the system configurations and technologies used [1].

Solar water pumps were used first time for water provision in off-grid rural areas. The technology has developed around many different system designs and in certain water pumps the consistency and maintenance requirements have enhanced over the basic pumps introduced to the market [2].

The microbiological community must be kept alive for the design of better and more effective filter. In an orthodox slow sand filter, oxygen is absorbed by organisms through dissolved oxygen in the water [2].

Another method for water filtration is reverse osmosis, which is the key method for water filtration in the European countries. However, commonly due to high energy cost, these technologies are not realistic application for poor developing countries. Due to limited alternative water sources, mostly large-scale reuse water schemes are in Israel, South Africa, and arid areas of USA. In many developing countries like The Philippines, has a major sanitation issue for both their urban and rural area citizens. Specifically for countryside citizens, according to 2008 Survey 17% of this countryside citizens still had no access to better-quality sanitation, with 14% estimated to be practicing open defecation. The Ferro cement biogas septic tank was installed as sanitation technology for individual families or small clusters of families [2]. All of the mentioned studies are useful and carefully examined by the researchers. Wastewater management will be of great help in conservation of water especially in the near future. Many researches are focus on environmental concerns because of the possible portable water shortage in the near future. The above mentioned literature is shown in Table 1.

2.2 For Water Automation

P. R. Panditrao et al. proposed a system to provide quality water filtration and cost effective recycling of water. Author demonstrate the new water filtration methods for domestic purposes can be combined together & automated using Programmable

Table 1 Existing methods for water purification

Parameters existing system for water purification	UV technology	Reverse osmosis	Sanitation technology
Installation expenditure	High	High	High
Maintenance expenditure	High	High	High
Area requirements	Very high	High	High
Power consumption	Very high	Very high	Very high
Purpose	Drinking	Drinking	Drinking

Table 2 Existing methods for automation

Parameters existing system for water automation	Raspberry pi	µc based	PLC
Installation expenditure	High	Less	High
Maintenance expenditure	High	Less	High
Area requirements	High	Very less	High
Power consumption	Very high	Less	High
Purpose	Drinking	Drinking	Domestic purpose

Logic Control to create a consistent & cost-effective system to get hygienic useable water. Mostly in India waste water or cleaning water from industries is dispose into natural fresh water resources such as rivers and lakes. When these natural resources saturate by industrial waste and several chemical impurities, the quality of water will automatically get reduce and downstream water are no more longer usable deprived of costly purification treatments. As per the reports of UNICEF industrial water productivity of India is very less and similarly very poor water treatment capacity use related to Indian population [1].

Rhowel Dellosa provides fully automatic filtered drinking water vending machine, which offering a touch less nozzle that can be used without a switch. Furthermore, accuracy is obtained by using Microcontroller Based Wastewater system. It is an automated vending machine that can provide a hygienic, reasonable and readily available drinking water [2].

Raspberry pi based automation is proposed by Sonali S. Lagu and et al. Automation plays a vital role in the hygienic, safe and consistent working of a water purification plant for providing pure drinking water. The efficiency of Plant is increased by using Raspberry Pi processor. Use of raspberry pi makes system more economic [3]. Table 2 shows the comparison of existing methods for automation of water purification system.

3 Overview of Proposed Smart Water System

In this system the bathroom basin, kitchen basin water is reused for gardening and toilet flush system. The basin water is passed through the "purifier system" which is used to purify the water for gardening as well as flush system. In this design the charcoal purifier, silica beads, alum, gravels sedimentation used so the water get purified as normal pH, value as it doesn't contain any acidic or alkali as well as removes odor, for this "Microcontroller system" is used to control flow of water and check turbidity of water. Sedimentation processes are good replacements for elimination the toxic composites from wastewater. Furthermore, by the use of the microcontroller accuracy and efficiency is increased. It is an automated system that can provide hygienic, affordable and readily available water for household usage. The system also gets rid of the unwanted color and odor of the water.

As well as "IOT system" is to be connected for incoming water supply and to check the real-time billing system. It also detects the "leakage of water" and monitors the usage of water. By using IOT the system can be controlled from any part of the world. IOT assure that the cloud is safe enough from all the external attacks and threats so that the customer does not affect a loss of data or data theft. Block diagram of smart water system is as shown in Fig. 1.

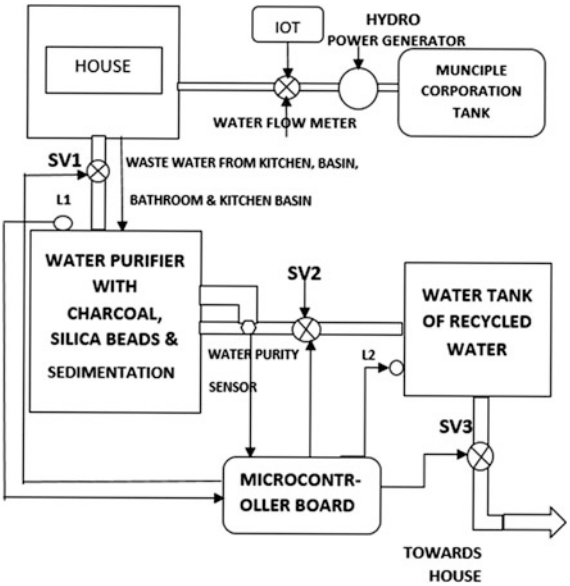


Fig. 1 Block diagram of smart water system

4 Water Purification

Polluted water is a major problem in front of today's world, since the high rate of population growth supplying pure water to each and every individual is a main challenge. The key idea behind the project is to make use of waste water by using simple filtration processes; combining it with the advance and cost effective technology to automate the whole water filtration plant to cut down the huge cost and man power required [1].

4.1 Block Diagram Waste Water Purification System

4.1.1 Proposed Model and Working

The waste water from houses is collected and subjected to filtration process. The filtration process involves the following steps:

(1) Cloth filtration
(2) Primary filtration using charcoal, silica, alum, gravels.
(3) Charcoal filtration and sedimentation
(4) Turbidity check
(5) Re-filtration (If required).

(As shown in Fig. 2), the water is passed through solenoid valve. Solenoid valve is an electromechanical operated valve. The valve used in this system is a normally-closed, direct-acting valve. The waste water from home passed through the solenoid valves, the solenoid valves are placed in system to control the flow of water between various stages.

In this purification process the water is then passed through cloth filter, the cloth filter reduces the pathogen count of almost 99%. Inexpensive cotton cloth or saree cloth, folded 4 to 8 times provides a filter of approximately 20 mm mesh size.

This is small enough to remove all zoo-plankton, phytoplankton and all v. cholera. Once the water undergoes to cloth filtration it needs to be disinfectant and further purified. Un-filter water is then passed over charcoal carbon bed. The carbon filtering is a method of filtering that uses the bed of activated carbon or charcoal carbon bed to remove impurities using chemical absorption process; it is most effective at removing organic compound like chlorine, sediment, volatile, taste and odor from water where as they are not effective at removing dissolved inorganic compounds and mineral salt. The water is than passed through Silica sand bed, Silica sand is used to clean and purify water. To capture suspended solids in water the natural silica filtration grade sand is used which has a sub-angular to rounded shape, making them an ideal filtration media. Next the water is passed through Aluminum sulphate when added to water reacts with the bicarbonate alkalinities present in water and forms a gelatinous precipitated. This floc attracts other

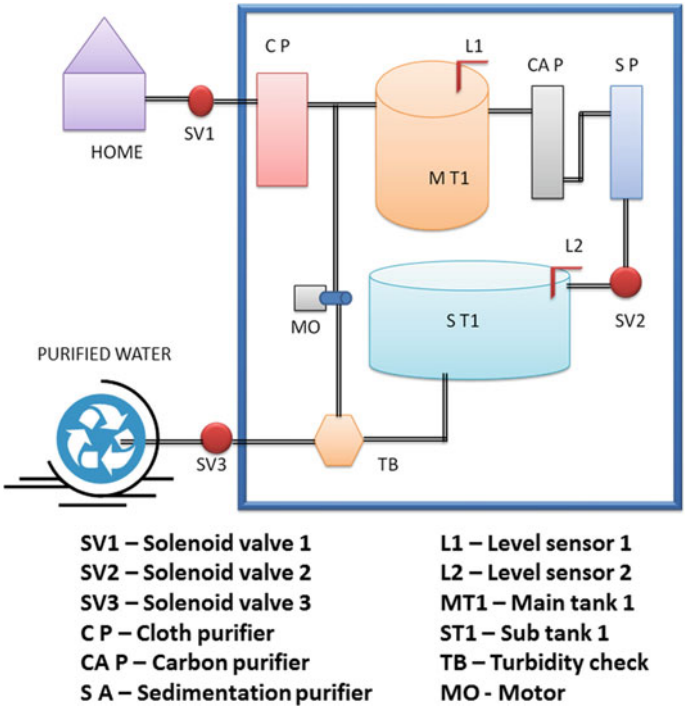


Fig. 2 Block diagram of waste water purification system

suspended materials and fine particles in water and settles down at the bottom surface. Next the layer of gravels are used as purification layer, gravel filter removes bacteria and other particles from water using simple filter and accessible technology. The water passes through the sand leaving suspended particle passing through the layer. The outcome should be clear water in carbon filtration, activated carbon works through a process called absorption whereby, pollutant molecules in the water to be treated are trapped inside the pore structure of the carbon substrate. Then water goes through sedimentation filter, Sedimentation is a process allowing suspended particles in water to settle down by allowing the water to stay still under the effect of gravity. Sedimentation is often use as a primary stage reducing the content of suspended solid as well as pollutant embedded in the suspended solid (as shown in flowchart). The purified water is then collected into the overhead tank; this purified water then goes through turbidity check using litmus paper. After going through the turbidity check if the water is found pure enough then it is supplied to the houses. Else, the water is sent to the primary tank for re-filtration. This process is repeated unless and until the water is satisfactorily pure.

4.1.2 Role of Microcontroller in the Automation of the Smart Water System

Components used in automation

1. Microcontroller 89C51
2. Level sensors—2
3. Water Flow sensor
4. ULN 2003 Solenoid driver
5. Solenoid valves—3.

(As shown in Fig. 3) A low power, high-performance Microcontroller is used, which is CMOS 8-bit microcontroller with 8 kb of flash programmable and erasable ROM (Read Only Memory). The main use of microcontroller is to control the flow of water and send the required information to the IOT.

Microcontroller is used to interface with solenoid driver ULN2003 which control the ON and OFF of the solenoid valves installed at various stages of purification and transmission of water.

Level sensor—The level sensor senses the water level at primary and secondary tank. Once the water in secondary tank is filled at its highest level it will give the indication through the level sensor to the microcontroller and solenoid valve 2 will be closed. The primary tank also contain level sensor, as the primary tank is full it will sense and will close the solenoid valve 1.

Water flow sensor—Water flow sensor are placed to detect the theft and leakage of the pipe at initial level of incoming water to house and give the information directly on the IOT. The water flow sensor will check the water pressure at the input and the output valve and show it on the IOT. If there is any leakage or

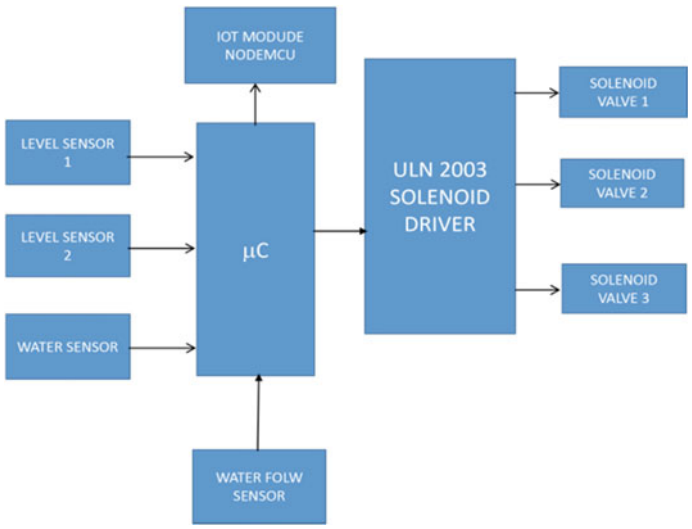


Fig. 3 Automation using microcontroller

theft then there will be back flow of the water and flow is calculated by determining the frequency of the pulse. To measure the flow rate following mathematical equation is used.

$$Flow\_Rate = Flow\_of\_water \times Common\_Factor$$

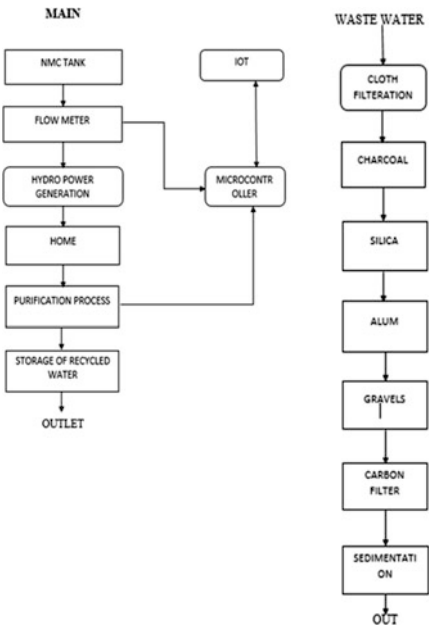
ULN 2003 Solenoid driver—ULN2003 Solenoid driver is used to interface all the 3 solenoid valves with the microcontroller 89C51. ULN203 is a high voltage, low power and high current Darlington array. It is a useful for driving a wide range of loads including solenoids, relay DC motors etc.

Solenoid valve—It is used to control water flow between various stages. There are 3 solenoid valve SV1, SV2, SV3.

SV1 is connected in front of flow meter which is used to ON and OFF of the process if the primary tank and Secondary tank is filled. SV2 is connected between primary and secondary tank. Once the secondary tank is filled up the level sensor will give the indication and SV2 will be closed. SV3 is connected at the end of the recycling system. Each and every solenoid valve are directly controlled by IOT module through microcontroller.

Water sensor—The water sensors is used to check that the water is present in the primary tank and secondary tank. It also checks the turbidity level of water by passing light through the water and checking the transparency of the water through photo detector (as shown in Fig. 3).

4.1.3 Flowchart for Sequence of Operation



5 Role of IOT in Theft Detection and Online Billing

5.1 Back End

1. *Consist of a database that contains the water flow from the flow meter as shown in* Fig. 4.
2. *Values from all the components (level sensors, solenoid valves, flow meter) are monitored and controlled.*
3. *The values from flow meter in the form of water pressure is collected and monitored.*

5.2 Front End

Since it is monitored and a trigger analysis (as shown in Fig. 5a–c). Alters are set to the concerned authorities in the form of SMS and mail. The mail is sent to the authorities in case of water pressure goes below threshold level set in accordance with house. If water pressure goes down the threshold level then system senses water leakage or theft and concerned authorities are alarmed (as shown in Fig. 6).

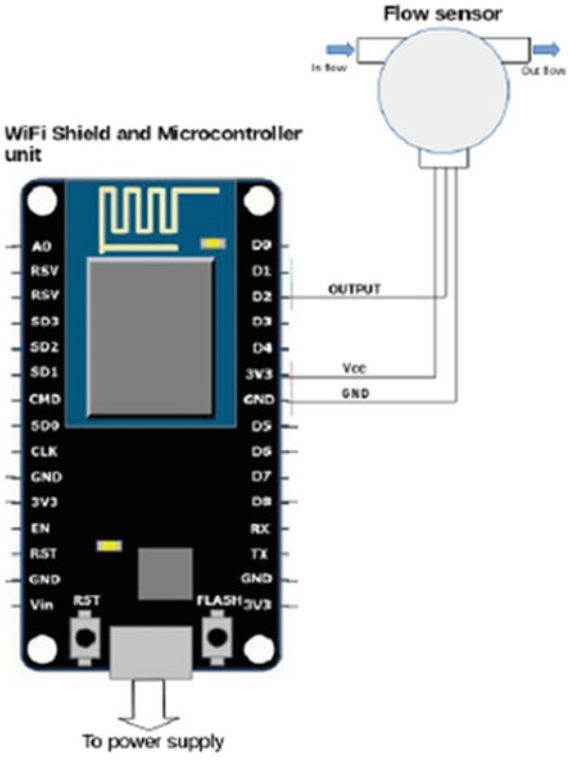


Fig. 4 Interfacing of node MCU with flow sensor

(a)

(b)

Window No.	Particular	Working
1	Water Pressure	Timeline
2	Level sensor	Timeline
3	Water Pressure	Water pressure controller (0-50)
4	Level sensor	Switch ON/OFF
5	Water Pressure	Water pressure meter (0-50)
6	Level sensor 1	ON/OFF showing full/empty(Red/Green)
7	Level sensor 2	0-OFF and 1-ON
8	Solenoid Valve 1	ON/OFF-[Green/Red]
9	Solenoid Valve 2	ON/OFF-[Green/Red]

(c)

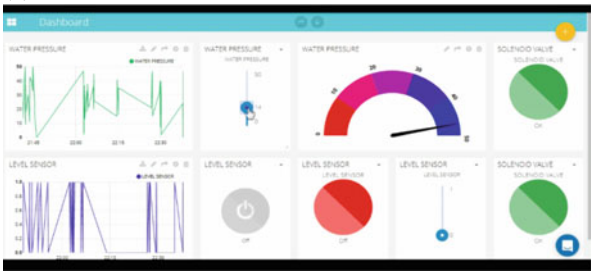


Fig. 5 **a** Initial stage of IOT monitor system. **b** IOT monitor system, Stage-1. **C** IOT monitor system, Stage-2

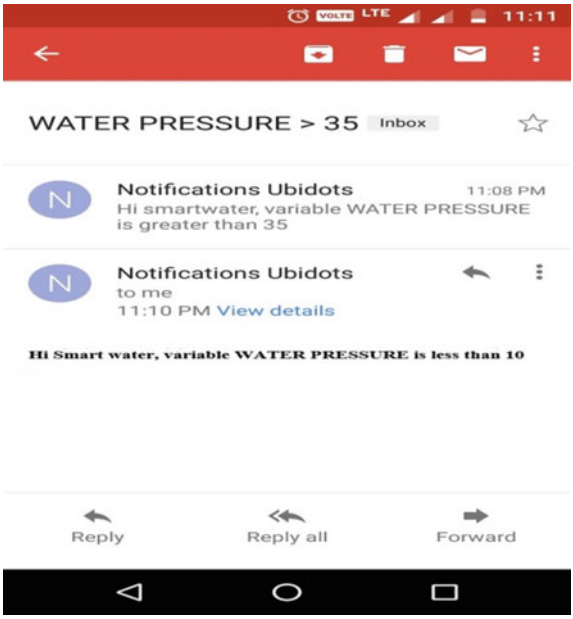


Fig. 6 Notification through e-mail

It monitors sensor reading and escalates the situations by altering to the authority and the municipal corporation [4, 5].

5.3 Email

Theft or leakage detection is as shown in Fig. 6 *i.e. notification through e-mail.*

5.4 IOT Purpose

4. *IOT is used to display real time value of flow of water.*
5. *Used for controlling solenoid valves.*
6. *Used to display the pressure of water from flow meter.*

6 Power Backup System by Using Hydropower Generation

Transformation of the energy of flowing water into electro mechanical energy is done by hydraulic turbine and a hydroelectric generator is used to converts this mechanical energy into electricity. The operation of a generator is based on the Faraday principles as shown in Fig. 7.

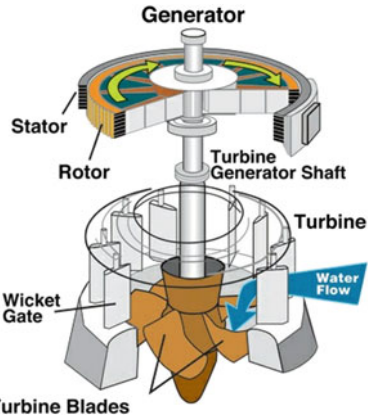


Fig. 7 Hydro power generator

The water strikes the turbine blades and turns the turbine, which is connected to a generator by a shaft. As the turbine blades turn, the rotor inside the generator also turns and electric current is produced as magnets rotate inside the fixed-coil generator to produce alternating current (AC).

The hydro power generator is connected between the municipal corporation tank and house provides power in terms of electricity by converting water pressure into electricity. Through this hydro power generator the amount of electricity produced is enough to power the system in case of absence of power or load shedding, so this system can work seamlessly and uninterruptedly. The power of system can be varied according to the water pressure on the turbine blades[6, 7].

As a working fluid, water in a hydropower system is not consumed, it is thus available for other uses. Diagram explanation (as shown in Fig. 7).Calculation of Power using Hydropower

$$Power = Head \times Flow \times Gravity$$

where;

The flow is the volume of water which can be captured and re-directed to turn the turbine generator. The head is the distance the water will fall on its way to the generator.

Where Power is measured in Watts, Head in meters, Flow in litres per second, and Acceleration due to Gravity in metres per Second Square. The acceleration due to gravity is approximately 9.81 m/s^2.

7 Conclusion

Use of IOT and microcontroller for system automation is a unique and advance technology. Computerized automation provides the hygienic and reliable operation of a smart water system in providing recycled water for gardening and flushing. Use

of Microcontroller simplifies the automation process and increases the overall efficiency of the system. Use of microcontroller enables to reduce the price of the system. In this system, the purification level/process is limited to some extent but depending on financial feasibility and requirement the purification level can be extended to Ultraviolet (UV) or even Reverse Osmosis (RO) purification so that it can be used for drinking purpose also. In this system IOT is extensively used for theft detection and online billing. This system has "Hydro-power generator" which generates power by flow of water & stores the energy in a Lithium-Ion battery, so in case of power failure it can provide power to the recycling system for uninterrupted service.

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