DCS Based Atmospheric Water Extractor For Domestic Use

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Abstract— Availability of fresh water, which is fit for consumption, has become a major concern due to its rising demand with rapidly increasing population. Also, there is high possibility of water, available at reservoirs, getting contaminated while transportation. A partial solution to this is to find new renewable sources of water, one of which is atmospheric water. It is the water present in air in the form of vapour which gets added to atmosphere by natural process of evaporation. The air containing water is termed as humid air and the measurement of the extent of humidness of air is termed as humidity. Coastal areas have the highest humidity values. This water, when extracted, can serve as a secondary source of water to people living in coastal areas. This would reduce the stress of water requirement on the reservoirs. The process of liquefaction of water from air is called condensation. It is done by lowering the temperature of air below its dew point, which is the temperature at which air gets saturated by its water content. There are machines called atmospheric water generators which use this process to extract water from air. The water is pure and safe for consumption. However, there are certain disadvantages of which one is their high power requirement per litre of water extracted. The goal of the industry is to reduce power requirement and increase yield of water of these machines. There are various applications of these systems such as for domestic consumers, in healthcare facilities, in military establishments, in industrial facilities etc.

Keywords: Water Extraction Unit, DCS CENTUM VP,UV Treatment, Humidity.

I. Introduction

Water is one of the most basic need of our society. In spite of all the technological advances we have made there are still more than a billion people facing serious problems regarding water availability. There are places where water is available but is impure and hence not usable. One of the reasons is the source of water. Of the total water on Earth, only 2.5% fresh water is available, of this 68% is captured in the form of glaciers, 30% in the form of ground water and remaining is distributed in lakes, rivers etc. This imposes a great constraint on our water utilization techniques. However there is another source of water which has still not been exploited which is atmospheric water [1]. Nature has provided us with an excellent water distribution system i.e. through air. When air flows over the surface of water it picks up some amount of it in the form of water vapour which we call as moisture. Air in the coastal region contains 70% to 80% of water in it which can be extracted by saturating it. This can be done by dropping the air temperature below its dew point which is termed as condensation. If we are able to extract this water it can solve a significant part of the water scarcity problem.

II. Objective:

To extract water from ambient air by employing condensing technology and purifying it so that it may conform to the World Health Organization drinking water quality standards.

• To improve the energy efficiency of the available method used for atmospheric water extraction.

• To reduce the amount of electrical energy required per litre of water (Watts/Litre).

• To study the working of DCS, interfacing of devices and programming of DCS.

• The interfaced system will be used to record, visualize, analyze and control real time data
from the model.

III. Block Diagram Of Atmospheric water extractor:

The unit for water extractor is shown below in figure 1.

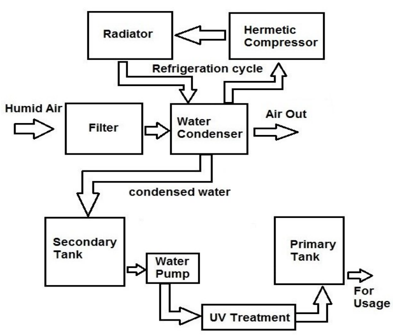

Fig. 1. Water Extractor Unit

IV. Operation:

1. The humid air is sucked in by a fan and then passed through HEPA filter.

2. The HEPA filter removes 99.9% of the dust particles from air.

3. The air is then made incident on the Water condenser whose temperature is controlled to be at or below the dew point of the air.

4. The water gets condensed and by the aid of gravity drops into the secondary tank.
5. The dehumidified air is exhausted out.
6. The water collected in the tank is then passed through the UV treatment unit which kill the microscopic bacteria and other microscopic organisms
7. This is done with the help of a water pump. The flow rate is about 2.5L/min which is the minimum flow rate required for the water to be passed through the UV unit for successful treatment.
8. The water is then collected and stored in the primary tank from which the water can be used[1].

V. Proposed work

The proposed model of Air Water Extractor works on the basis of refrigeration principle, which states that refrigeration, is a process in which heat transfers from one location to another. This is carried out traditionally driven by mechanical work, but can also be driven by heat, electricity, magnetism, laser or other means. The refrigerant gas will be filled in the compressor by using nozzle. The compressor will compress the refrigerant which is filled in system which converts low pressure vapour into high pressure vapour. Then it moves from the compressor for condensation of the gas stream and made it to high pressure liquid then passes to expansion valve i.e. capillary tube where expansion valve will control the flow of airstream which is in the form of high pressure liquid. This get converted to the evaporator chamber, in the form of low pressure liquid. A controlled speed fan pushes filtered air over the coil. Here the temperature difference among refrigerant and atmospheric moisture the water droplets are formed on the surface of evaporator tubes and falls into a tank due to gravity. The resulting water is then passed into a holding tank for purification and filtration system which include a UV treatment unit to help keep the water pure and reduce the risk of impurity which may be collected from the ambient air on the evaporator coil by the condensing water.

The closed loop systems that are being controlled in the proposed model include the following:

1. The speed of the fan is controlled by sensing the temperature and humidity of the atmosphere.

A surface mounted RTD is used as temperature sensor for feedback loop.

2. The compressor is in continuous running mode. The speed of the compressor will be switched between two fixed values using relay and ON/OFF controller to control the temperature of the water condenser.

3. The speed of the motor is controlled using PWM AC motor speed control.

4. The transfer of water from Secondary tank to Primary tank will be controlled by sensing the level of water in the secondary tank. As soon as the secondary as well as the primary tank levels reaches their upper limit the system will stop the extraction process.

VI. Hardware and Software Components

VI.a. Distributed Control System(Hardware components)

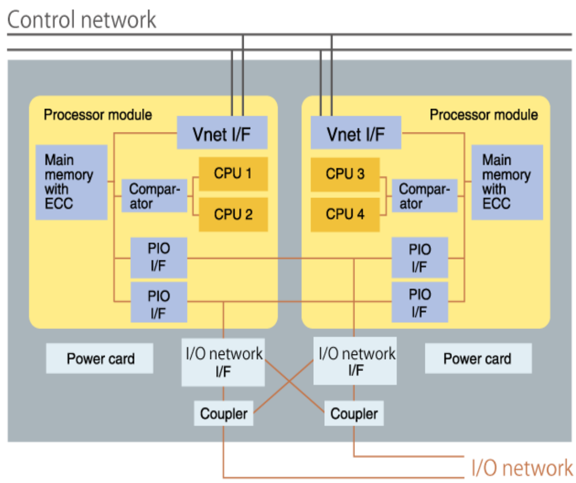

Fig.2. Block Diagram of Yokogawa CENTUM

A distributed control system (DCS) is a computerized control system for a process or plant usually with a large number of control loops, in which autonomous controllers are distributed throughout the system, but there is central operator supervisory control.

DCS: Yokogawa Centum VP

Yokogawa Centum VP consists of Human Interface Station (HIS), Engineering Station (ENG), Field Control Station (FCS), Safety Control Station (SCS), I/O Modules, Bus converter (BCV), System Integration OPC Station (SIOS), Control Network (Vnet/IP), Field Digital Network illustrated in figure 2.

VI.b. Software Components

Yokogawa DCS Centum VP software consists of the following features:

• To view and control the process using GUI, same as the real process (SCADA).• Programming environment wherein logic can be created developed

• A hierarchical view of the whole system

• Advance Control Strategy Schemes

• Configuration Suite for the hardware attached.
• Diagnostic Suite
• Alarm, History and Trends Module
• Database management module

VII. Design and Implementation

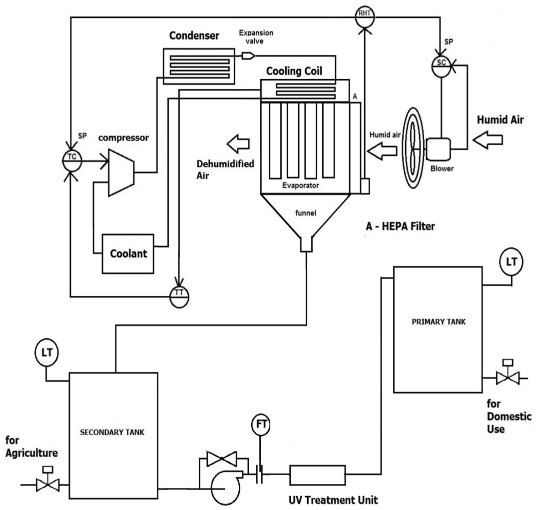

Fig. 3. Water Extractor Unit

VII.1. Work Flow of Water Extractor

1. As soon as the Level of secondary tank L2 drops below the lower limit the water extraction process will start.
2. The compressor is started at minimum speed, the suction and exhaust fans are started. The speed of suction fan is controlled based on the RH value of the air. Set point is provided by RH value transmitter and feedback through tachometer. The speed of the motor is controlled using PWM AC motor speed control.
3. The compressor has three main ports viz. suction, discharge and charging port. The refrigerant is sucked through the suction port and then compressed by the piston. Due to high compression, the refrigerant attains a very high temperature of about 55 to 60°C. To reduce this temperature the gas is passed through a condenser via the discharge port which retains the pressure while reducing the temperature to about 35 to 40°C. The refrigerant gets liquefied in this process.
4. The liquefied refrigerant is then passed through a capillary and then released into the cooling coil through an expansion valve which has an extremely small opening. As soon as the refrigerant is released it gets vaporized due to sudden expansion and its temperature drops below 0°C. This is used to remove heat from the system and the heated refrigerant is then again passed through the same refrigeration cycle.
5. The compressor is in continuous running mode. The speed of the compressor will be switched between two fixed values using relay and ON/OFF controller to control the temperature of the water condenser.
6. The temperature set point is provided by the RH sensor which is the dew point calculated using August-Roche-Magnus approximation method. Surface mount RTD will be used as the temperature sensor for feedback.
7. The water condenser will be enclosed in a thermally insulated chamber to improve efficiency.
8. As soon as the secondary as well as the primary tank levels reaches their upper limit the system will stop the extraction process.
9. The extracted water will then be collected into the secondary tank from where it will be UV treated and then stored into the primary tank[2][5].

VII.2. Work Flow of Water UV treatment and storage unit

1. The UV treatment unit ensures that the obtained water is free from any harmful microscopic organisms.
2. The Level of primary tank L1 and of secondary tank L2 are the control variables. As soon as the Level in the primary tank drops below the lower limit the unit starts its operation and transfers the collected water from secondary tank to the primary tank through the UV treatment equipment.
3. The water stored in the primary tank can also be retreated manually by opening hand valve HV1.

VII.3. Tank level measurement using ultrasonic sensor

Ultrasonic Sensor (HR-SR04) works on the principle of reflection of sound waves from the surface of water[4]. The trig pin is given a pulse which actuates the transmitter to transmit a burst of ultrasonic sound wave of a fixed width which is reflected from the surface of the water and
picked up by the receiver and is read from the echo pin. The distance between the sensor and the surface is calculated as

$$D=v{:}t/2 \quad (1)$$

where: D is the distance between sensor and surface of water
v is the speed of sound in air which is 320 m/sec
t = time interval between transmission and reception of the ultrasonic sound wave
The level of water in the tank is the difference between the height of the sensor from tank bottom and the distance measured by ultrasonic sensor

Level=H-D (2)

where: H is the height of the sensor from the tank bottom

Flow measurement using Hall effect flow meter

The YF-S201 is a Hall Effect based flow meter. It contains a runner blade through which the water flows causing the blades to rotate. The rotation is sensed by the Hall Effect sensor which then produces a pulse train of a particular frequency. The frequency of these pulses is related to the flow rate by the following relation.

Flow-rate(L=min)=f/7:5 (3)

where: f is frequency of pulse train in Hz

Input List:

1. FLRT - FLOWRATE STATUS
2. LS-01 - PRIMARY TANK LEVEL
3. LS-02 - SECONDARY TANK MID LEVEL
4. %%PTT0001 - TEMPERATURE FEEDBACK
5. %%RHT0101 - RELATIVE HUMIDITY
6. %%PTY1001 - TEMPERATURE SETPOINT

Output List:

1. UV - UV ON/OFF
2. WTR PUMP - WATER PUMP ON/OFF
3. TS - TANK SELECTION
4. TRST - TANK SELECTION RESET
5. FAN SWITCH - FAN ON/OFF
6. COMPR SWITCH - COMPRESSOR ON/OFF
7. COMPR SPEED - COMPRESSOR SPEED CONTROL
8. COMPR CAPD - COMPRESSOR CAPACITOR DISCHARGE

VIII. Atmospheric Water Extractor model

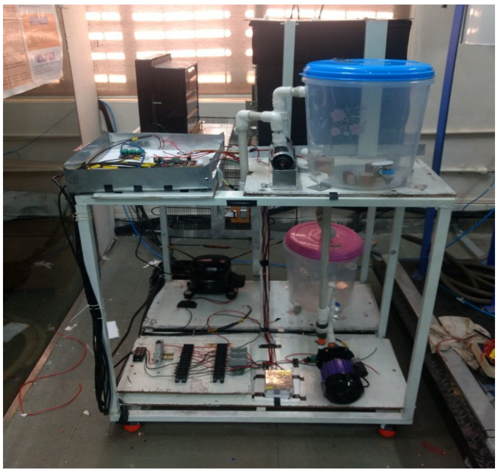

Fig.4. Working Model

The practical working model for Atmospheric Water extractor is shown above.

Flowchart and Algorithm

A detailed control flow diagram of the water extractor is shown below:

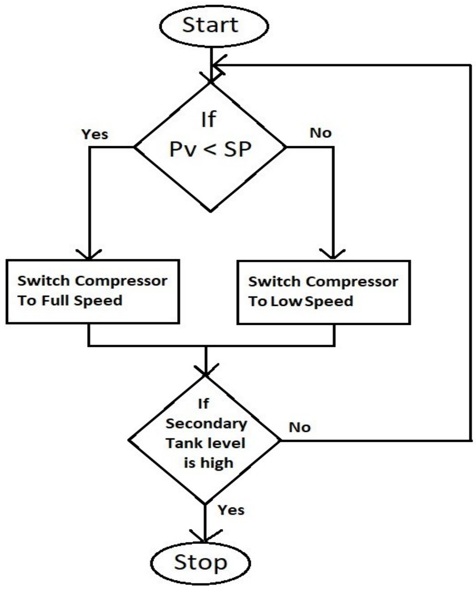

Fig.5. Flow diagram of working of Water Extractor

IX. Results and discussion

Parameters	Condn 1	Condn 2	Condn 3
RH value	>75%	75%>RH > 45%	< 45%
Temperature	25 °C +/- 3	25 °C +/- 3	25 °C +/- 3
Compressor mode	Cont. running mode	Cont. running mode	Cont. running mode
Water Extracted (L/hr.) +/- 10% (average)	N.A.	137	N.A.
Power Consumption (kWh)	135	135	135

Table 1: Test Results

The test Results of the system for different conditions are as follows:
*Minimum 20% and Maximum 90% RH value has been considered.

Test Results:

1. August-Roche-Magnus approximation holds true for condensation with 10-15% error.
2. The condensation temperature is inversely proportional to RH value and hence the system
would require more energy in areas with low humidity values.
3. The system consumes significantly less energy, about 30% less, when compressor is used in continuous running mode as compared to usual ON/OFF controller.
4. The cost of water, obtained, per litre is very less, approx. Rs. 3/L, as compared to bottled water, Rs. 20/L, with much higher purity.
5. The quantity of water is also dependent on the surface areaavailable for condensation. In our system 6361.72 cm^2 of surface area was available for condensation. This can be increased by scaling the Water Extraction chamber suitably.

X. Conclusion and Future Scope

X.a. Conclusion

The project can be applied in large scale in developing countries. It reflects like a renewable source of water and does not need a heavy power source. The application of this technology may result in solution for water supply problems in many situations
It works in optimum envirnment of energy sources It could create additional potable water. Thus it csn helps the society to tackle the problem regarding availability of pure drinking water in remote locations, mining sites and instances where water scaling biggest problem. Also it requires less man power, time and it does not cause any pollution. The Atmospheric Water Extractor can be used in numerous different areas, some of them are listed below:
1. The Atmospheric Water Extractor units can be used by communities in countries which lack access to fresh water source.
2. In Hospitals and Healthcare facilities for primary or emergency back-up fresh water
generation.
3. In Commercial and Industrial facilities.
4. It can be used in laboratries since the water obtained is 100% pure and can be used as distilled water for various experiments or laboratory activities.
5. The water obtained can be used for Drip Irrigation purpose.

X.b. Future Scope

This project employs a Vapor Compression Refrigeration (VCR) system for condensation. These systems are bulky. But there are research being carried out to improve the efficiency of these devices. If and when an acceptable efficiency has been achieved it can be used in place of the VCR system. The devices being small can be used to develop portable self-filing water bottles.

Acknowledgment

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References

References:

[1] Santanu Prasad Datta, Prasanta Kumar Das, Siddhartha Mukhopadhyay "*Effect of Refrigerant Charge, Compressor Speed and Air Flow Through the Evaporator on the Performance of an Automotive Air Conditioning System"* International Refrigeration and Air Conditioning Conference. 2014 http://docs.lib.purdue.edu/iracc/1470.

[2] P. Binneberg, E. Kraus, H. Quack *"Reduction In Power Consumption Of Household Refrigerators By Using Variable Speed Compressors"* International Refrigeration and Air Conditioning Conference.2002 http://docs.lib.purdue.edu/iracc/615

[3] Alessandro Scrivania, Ugo Bardib "A study of the use of solar concentrating plants for the atmospheric water vapour extraction from ambient air in the Middle East and Northern Africa region" the conference on Desalination and the Environment. Sponsored by the European Desalination Society and Center for Research and Technology Hellas (CERTH), Sani Resort, Halkidiki, Greece, April 22–25, 2007.

[4] A.E. Kabeel, Mohammad Abdulaziz, Emad M.S., EI-Said "*Solar-based atmospheric water generator utilisation of a*

fresh water recovery: A numerical study" International Journal on Ambient Energy, Vol. 37, Pages 68-75, Issue 1, Oct. 2013.

[5] Sahil Doshi, Shubham Chaudhari, Saheel Aitwade, Ratan Singh, and C. P. Waykole *"Development of Water Generation System from Air"* International Journal of Current Engineering and Technology, Special Issue-4 E-ISSN 2277 – 4106, P-ISSN 2347 – 5161 ©2016 INPRESSCO. Available at http://inpressco.com/category/ijcet

[6] Anna Magrini, Lucia Cattani, Marco Cartesegna, Lorenza Magnani "*Water Production from Air Conditioning Systems: Some Evaluations about a Sustainable Use of Resources"* Sustainability2017,9, 1309; doi:10.3390/su9081309 www.mdpi.com/journal/sustainability