International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 5 Issue 7, July 2018

ISSN: 2394-4404

Solar Powered Wireless Sensor Network For Pipeline Monitoring System

Reshma H

Student M.Tech, Department of Electrical & Electronics Engineering, The National Institute of Engineering, Mysore, India

Radha R

Associate Professor, Department of Electrical & Electronics Engineering, The National Institute of Engineering, Mysore, India

Abstract: ***In this project, a 16-bit MSP430 controller version with an android app is uniquely intended for an incessant crude oil pipeline monitoring and communication about the distance of 1350 Km from pumping station to harbor stockpiling tanks with 135 DCS station. Existing framework running on OFC and wired link to exchange data amongst stations and field engineers, have its own particular confinement, for instance consistent upkeep, transportation, and dedicated personnel which costs more to oil organization. It is inquisitive to build up a hub which must create energy of its own and should exchange information through secured remote system with low bandwidth, which must play all the procedure without human interference and must carry out the work which current system is doing. It will be implemented by building up a framework which gets power from solar panel and stores that same into battery banks. Put away power will be utilized by controller to screen fire, temperature, and levels and transmit SoS information utilizing Wi-Fi with MQTT architecture uncommonly intended for low bandwidth link by IBM Corporation. Expected outcome of this outline will utilize dedicated hub for every station with a secured IP and QoS level three secured MQTT with fixed sensors, dedicated low power controller with an energy harvester will be interfaced and specific firmware utilizing RTOS will be created to do the undertakings.***

Keywords: ***Pipeline monitoring, MSP430 controller, Distributed Control System (DCS), Optical Fibre Cable (OFC), Message Queuing Telemetry Transport (MQTT), Real Time Operating System (RTOS), Quality Operating Service (QoS).***

I. INTRODUCTION

The proposed WSN equipment is used to scan the sensor status installed in the pipeline and send the required information utilizing dedicated low bandwidth with secured QoS level three. This system generates energy for its own by using solar panel and stores it in battery banks. Low power controller with Wi-Fi developed by Texas instruments has been utilized to design working prototype.

In recent innovation on WSN's for automation purpose which covers wide zone like water, fuel, gas etc. playing its own role. A minor variation or human error can lead to major uncontrollable damages or even loss of ecological life. Complex network will lead to clog in network traffic and also consumes huge bandwidth to transfer the data which leads to more equipment, more power consumption and multiple repeaters. This network uses a dedicated server which will lack in performance leads to loss of data or delay in communication due to numerous hubs imparting at once. Monitoring and processing data in real time with each node is considered as critical part due to highly combustible material passing through the pipeline, any fiasco can occur at any time which the dedicated personnel is not aware what is happening, which leads the disaster to go out of control causing huge damages and it will take number of days to repair it and bring the system to normal.

II. ADVANTAGES OF MQTT AND WSN TECHNOLOGY

MQTT and WSN Technology in crude oil pipeline have many advantages and some of them are listed as follows.

- ✓ Optimizing power management.
- ✓ No error due to human interference.
- ✓ Compatibility and remote management.
- ✓ Dual control makes scalability for customized control.
- ✓ Wi-Fi operation gives inter user control for flexible operation.
- ✓ Easy to install.

III. OVERVIEW OF THE PROJECT

The main aim of this project is to develop a node based system with the feature of detection of leakage and identification of any threat in real-time. It must generate energy for its own and should exchange information through a secured remote system with low bandwidth, without human interference. Secured, reliable, and efficient system. And also it must fiscally sharp, flexible, and easily versatile system. The following are the goals of the work:

- ✓ To design prototype of MCU with dedicated apparatus.
- ✓ To provide the gateway on MQTT using QoS for a secured link communication using reserved IP [1].
- ✓ Create an android app to access the log as well as get the messages regarding the status of sensors.
- ✓ Design an efficient Dc-Dc converter for harvesting of energy.

IV. SYSTEM METHODOLOGY

The complete block diagram of proposed system is shown in Figure 1, which has three sensors interfaced to the processor. Various operations are handled by MSP controller (MSP430F5529).

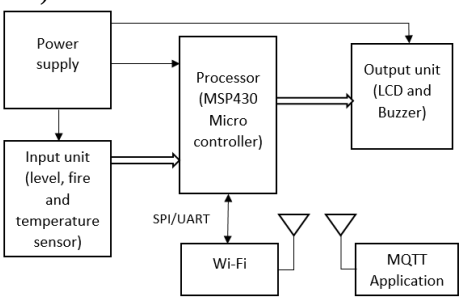

Figure 1: System Block Diagram of Monitoring and Communication Unit (MCU)

TI-RTOS with task including communication is loaded into SOC for continuous monitoring of various sensors and also for proper scheduling of tasks. Wi-Fi module is interfaced with MSP using SPI which connects to AWS using reserved IP and a gateway port for the purpose of publishing messages to respective topics. Subscription to corresponding topic published by user using Wi-Fi must be done to receive message. Access between AWS client and host is done using light weight MQTT protocol.

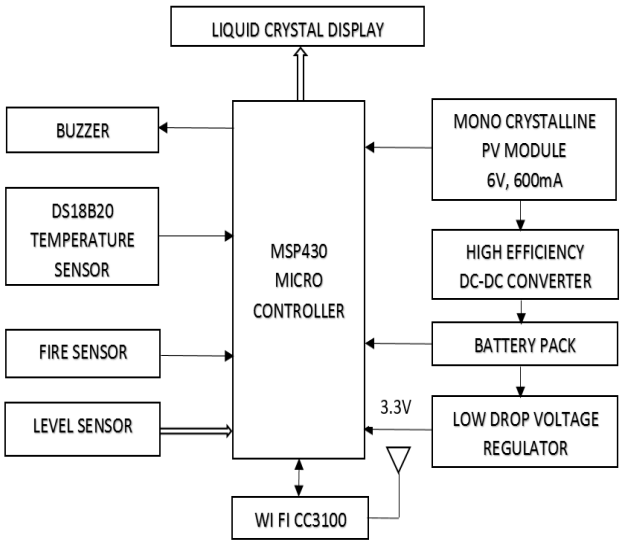

Figure 2: System Block Diagram of Monitoring Unit

Figure 2 shows the block diagram of monitoring unit of the system. This system shows the monitoring of different elements status. Mono crystalline PV rated at 6 V, 600 mA is used to generate power by converting light into electricity. Output of the panel varies depending on light intensity. Low intensity causes lag in charging of battery. To overcome this issue dc-dc converter is used which boost the voltage obtained from panel to a suitable level for charging voltage of 5V. Sealed Lead-Acid battery is used to provide persistent power to node for its operation.

This system works at low power 3.3 V at 300 mA, but output of the battery bank is about 7 V. To reduce this voltage to 3.3 V, LM1117 LDO voltage regulator is used. LCD provides visible information of temperature in degree centigrade, fluid levels, fire and smoke sensor status.

To alert nearby engineers in case of any SoS an audible information is generated by piezoelectric buzzer operating at 3 kHz.

Block diagram of node connection to network with client interface is shown in Figure 3. This block is divided into two segments. Segment one is node, segment two is cloud with MQTT broker and user end application. Node will access to MQTT broker by connecting to master which must have internet access. Node connects to this modem by using join network command with a SSID and a password which is a 128-bit encryption. As soon as node is connected to master, then broker automatically connects to AWS and starts publishing or subscribing the messages with topic. MQTT is connected to both node and user. User can access the information by running the mobile app which is developed using android studio. When app is executed with data link ON, port will be automatically forwarded to AWS server where processed information from node and client will be stored.

ISSN: 2394-4404

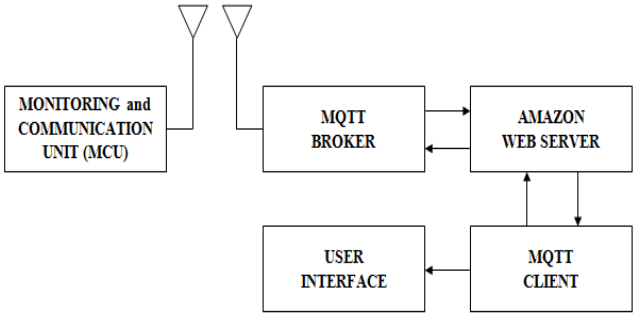

Figure 3: Communication Block

Broker structure shown in Figure 4 describes the MQTT message handling which incorporates publisher, subscriber and a broker. The key components of the broker are light weight message queuing and transport protocol, which is used to publish the series of messages to the cloud. The events or messages are of asynchronous communication model. This protocol is chosen for this design because of its low overhead, 2 byte header for slower network bandwidth application. Publishing and subscribing topic for the corresponding messages via link broker through AWS can be handled in easy way.

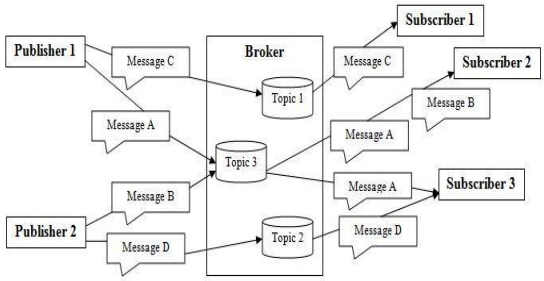

Figure 3: MQTT Message Handling Structure

V. HARDWARE REQUIREMENT

WSN based data acquisition and analysis is done to get required log with SoS message using MQTT Protocol utilizing the following hardware equipment.

A. MSP430F5529 MICROCONTROLLER

The MSP430 development board as shown in Figure 5 is divided into three segments. One is GPIO part, second is emulator and third is USB HID. MSP430F5529LP is an 80 pin, 16-bit RISC controller manufactured by TI. In this IC there are 56 I/O lines grouped into seven ports. This IC has 128 kB high speed flash and 8 kB RAM with four serial interface, ADC, five timers and a full speed USB support for debug and application loading. This IC operates from 1.8 to 3.6 V with 25 MHz internal clock and 33 MHz external clock. All the ADC channel are 12-bit in resolution. Execution speed of this controller is 500 ns per instruction with a throughput of 32 MIPS at 25 MHz.

This launch pad has only 40 pin connection which is also known as booster pack pin out which includes eight analog channels, UART, I^2C, SPI and rest are GPIOs.

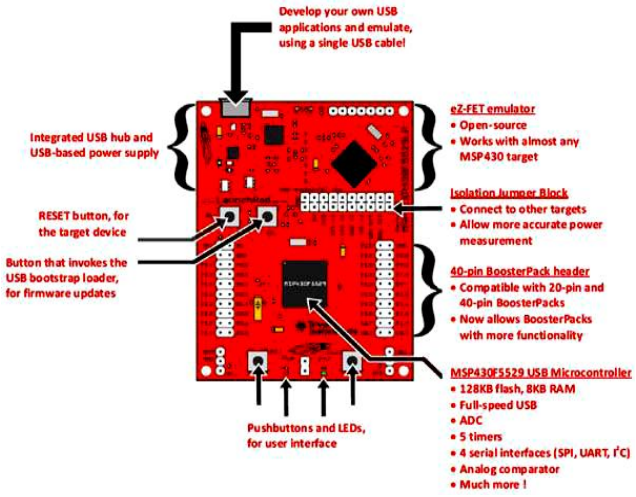

Figure 5: Overview of Launch Pad

B. WI-FI CC3100

Figure 6 shows Wi-Fi CC3100 which is featured with a dedicated ARM 32-bit controller with multiple protocols for internet stored in ROM. It is based on 802.11 b/g/n radio with MAC and its supplicant with in-built TCP/IP stack for BSD application for socket. It also features 256-bit AES encryption with powerful crypto engine for secured connection based on TLS and SSL certified links. It can also be configured as station, access point, Ad-hoc with WPA2 security. TX power at 18.0 dBm @ 1 DSSS, 14.5 dBm @ 54 OFDM, RX sensitivity -95.7 dBm @ 1 DSSS, -74.0 dBm @ 54 OFDM up to 16 Mbps in UDP and 13 Mbps in TCP mode. This system operates at 2.1 to 3.6 V and consumes maximum 223 mA for TX @ 54 OFDM, 53 mA for RX @ 54 OFDM.

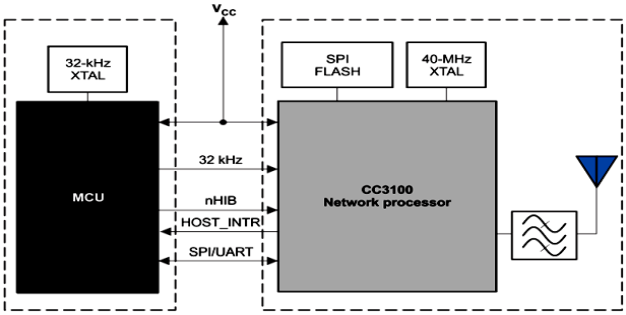

Figure 6: Connection Diagram of CC3100

C. DS18B20 TEMPERATURE SENSOR

1-Wire is a protocol designed by DS Corporation to utilize one I/O to send and receive data with low speed provides solitary signal control and flagging compared to I^2C. This protocol is intended for small devices with lower transfer speed for example thermometers, climate gadgets etc. This 1-Wire is also called as micro-LAN. One important feature of this bus is it utilizes data (DQ) and ground. To execute this, gadgets are incorporated with an 800 pF storage capacitor amid the gadgets where data line is used for information.

ISSN: 2394-4404

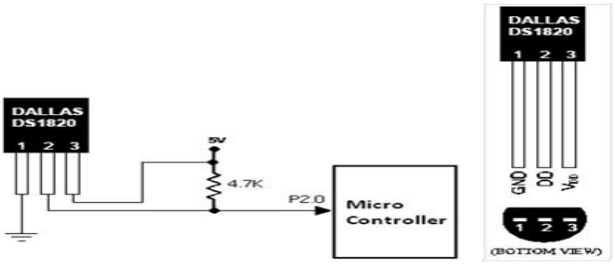

Figure 7: Interfacing DS18B20 to Microcontroller

Figure 7 shows the pin connection with a 4.7 kΩ pull up resistor connected between DQ line and Vcc. This pin acts as bi-direction depends on the master pulling up or down the line with respect to Vcc and ground.

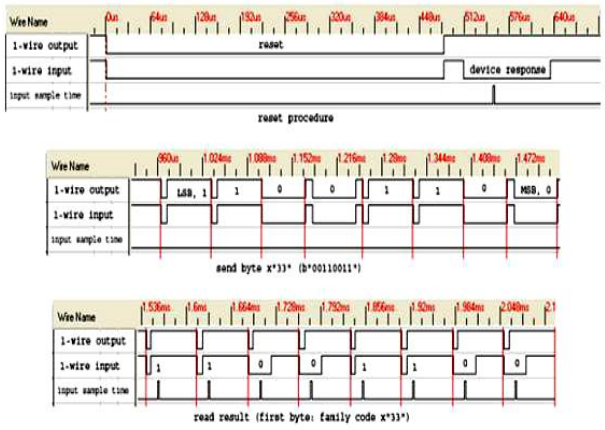

Figure 8: Waveform of the DS18B20 Simulated on Scope

Figure 8 shows three different timing cycles used to reset, send byte and read results. Master makes DQ line low for 448 µs to identify the device. After this, line will be pulled up for 4 µs. If device is present, line will be pulled down for some µs. If device is not present then line will not be pulled low by sensor. Send byte waveform shows different timing with data 0x33 transferred in the format of binary. Read result waveform shows first byte information for the code 0x33 generated by DS sensor.

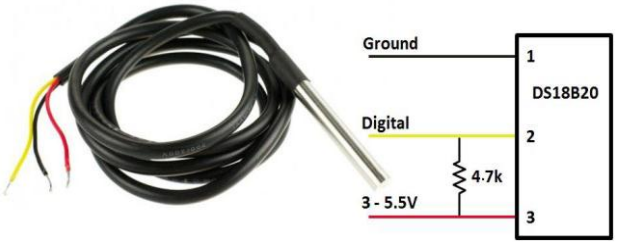

Figure 9: Spill Proof Temperature Sensor

Serial code of 64-bit is integrated into this temperature sensor which allows various series of similar sensor type to work using protocol of 1-Wire. Figure 9 shows a spill proof temperature sensor which has one chip for numerous operations.

D. FIRE SENSOR

Fire sensors comes in various types, optical detector is one of its type that uses thermal infrared radiation generated by a blaze. The other types are ionization, thermocouple which uses nearness of fire using current stream.

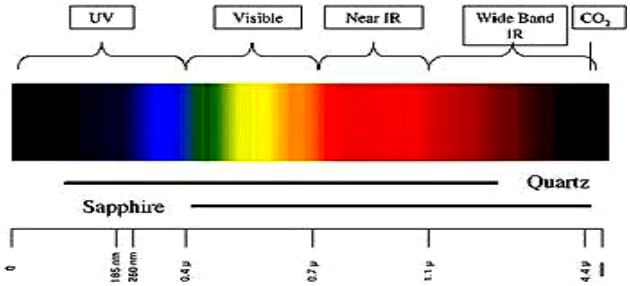

Figure 10: Different Spectrums for Light Source

Figure 10 shows the visible and infrared spectrum of different source of light. To detect corresponding radiation a circuit is been developed as shown in Figure 11 which uses LM358 dual operational amplifier configured as comparator, and a photo-sensitive diode is used. Photodiode is connected in reverse biased with a 1 kΩ resistor connected to pin number 3 of op-amp. Second pin is connected to 50 kΩ POT for adjustment of sensitivity with a 1 kΩ resistor in series to Vcc. Output of this op-amp is connected to fifth pin of second comparator. Sixth pin is connected to voltage divider with a reference of 1.25 V. Output is taken from pin number 7 and connected to microcontroller for further processing.

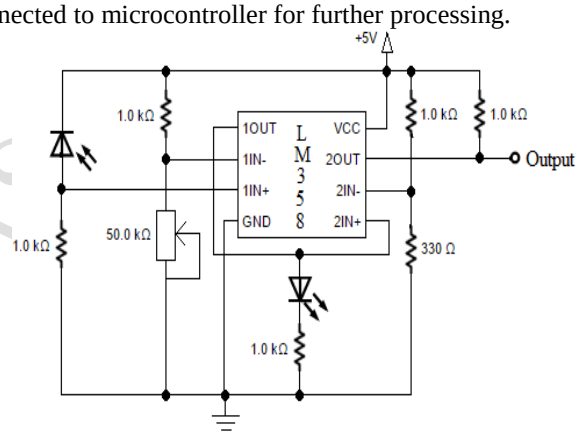

Figure 11: Circuit Diagram of Fire Sensor

E. LEVEL PROBES

These sensors are used to monitor contained space free flowing substance with regulated levels which are usually liquid. These probes also can monitor flowing powdered substance which are widely used in industry, automobile fuel gauges, storage tanks, slurry etc. There are multi type level sensors used for detection of different fluids for example magnet, reed, float, capacitive, inductive etc.

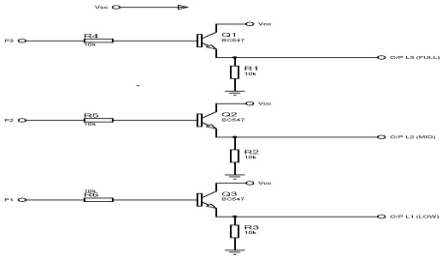

Figure 12: Level Sensor circuit diagram

Another name for this level is called conductive as shown in Figure 13 which allows only liquid to detect its level by passing electricity from reference node to sensing node which is done by powering up one node with a low voltage and

ISSN: 2394-4404

another nodes placed at different position. When conductive liquid reaches desired point level, voltage generated from reference node will be passed to conductive node. Outputs of the sensor are usually in the form of digital.

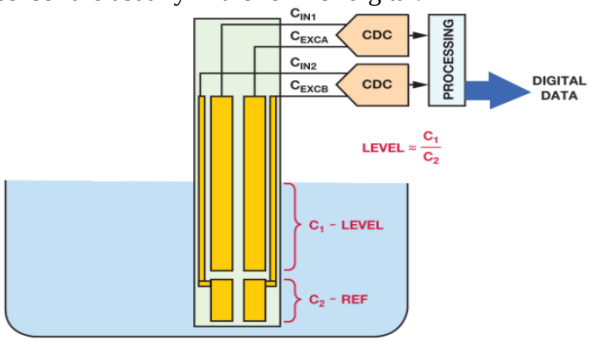

Figure 13: Level Sensor Arrangement

F. MONO CRYSTALLINE SOLAR PANEL

PV cells shown in Figure 14 are used to convert light into electricity by a photosensitive p-n junction diode, acts as forward biased when light falls on the junction that causes electrons to move from p-to-n allowing an voltage to flow. This system uses mono crystalline solar panel fabricated by silicon-di-oxide of type quartzite, gravel or crushed quartz usually in the form of silica. Mono crystalline solar panel is preferred because of durable performance which is commonly used in space shuttles. Durability of this system can last up to 50 years. PV made of mono crystalline cells can convert utmost incident light into electricity compared to any other cells available makes this PV more efficient.

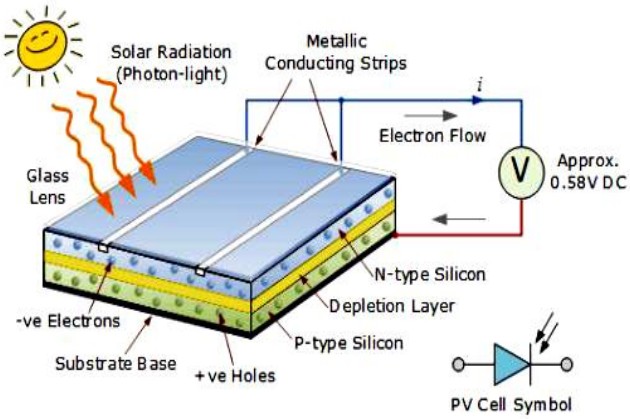

Figure 14: Internal Structure of PV Cell

With thin-film solar panel for embedded energy at lower rate negates the size needed very less to mount. This panel offers very greater heat resistance from 50° C to 150° C with only 12-15% loss in efficiency compared to previous cells. This panel can generate more electricity per sq.m compared to other panels.

G. LM2577 DC-DC CONVERTER

Monolithic IC shown in Figure 15 is used for power control step up and fly-back forward converters. This IC uses minimum external components simple to use and very less in cost. This is a 3 A boost converter of NPN switch type with in-built 52 kHz FFO. This IC also has soft start mode which reduces any possible in rush current. Current mode provides improved rejection of any transients.

Figure 15: Pin Details of LM2577

Figure 16 shows the circuit with required components to boost incoming voltage from 5–6.6 V from solar panel to 7 V to charge the battery. This circuit's output will be high and low at 52 kHz frequency which indirectly generates energy during NPN is ON with inductor. The current in the inductor which charges to Vin/L is called as inductor storage current. When it goes low to lower inductor's end, Vin discharges by flying above its current via diode to the capacitor at (Vout-Vin)/L. When SW is OFF, stored energy in inductor will be transferred.

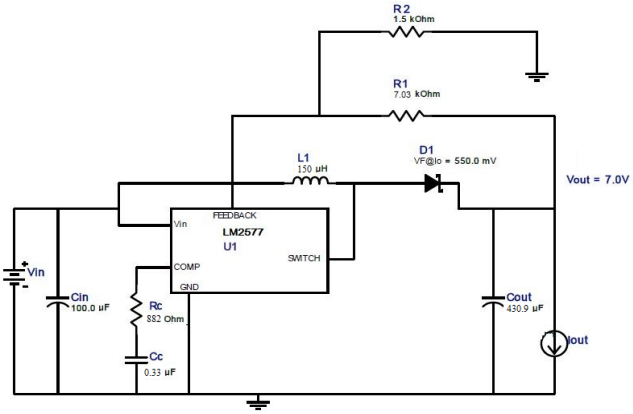

Figure 16: Application Circuit of DC-DC circuit

Voltage and current waveforms of step-up regulator shown in Figure 17 gives detailed representation of diode, inductor and switching voltage and current with respect to Vsat, Vf , Vr, Ind(ave), Isw(pk), Id(pk).

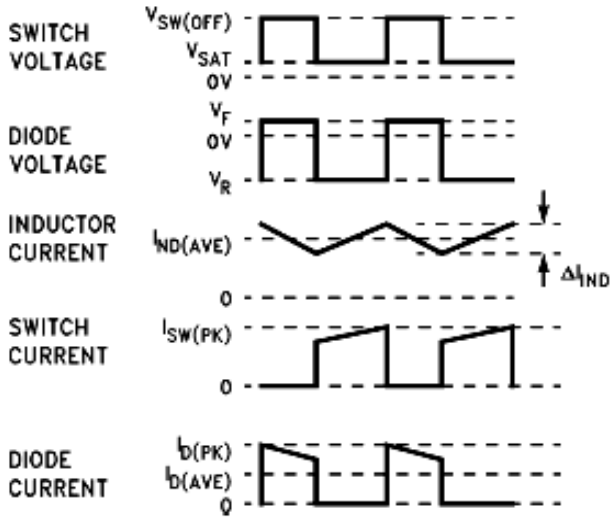

Figure 17: Step-Up Regulator Waveforms

Design of Inductor, Compensation network and resistors used in dc-dc converter circuit:

Parameter considered are $V_{IN(min)} = 5V$, $V_{OUT} = 7V$, $I_{L(max)} = 600mA$, $V_F = 0.5V$ and $C_{IN} = 100\mu F$.

(1) Design of inductor
The maximum duty cycle of switch is

$$D_{(max)} = \frac{V_{OUT}+V_F-V_{IN(min)}}{V_{OUT}+V_F-0.6V}. \quad (3.1)$$

$$D_{(max)} = \frac{7V+0.5V-5V}{7V+0.5V-0.6V} = 0.362.$$

The product of volts x time that charges the inductor is

$$E*T = \frac{D_{(max)}(V_{IN(min)}-0.6V)10^6}{52\,kHz}. \quad (3.2)$$

$$E*T = \frac{0.362(5V-0.6V)10^6}{52kHz} = 30.63V\mu s.$$

Average current of the inductor under full load is

$$I_{IND,DC} = \frac{1.05\times I_{L(max)}}{1-D_{(max)}}. \quad (3.3)$$

$$I_{IND,DC} = \frac{1.05\times 600mA}{1-0.362} = 0.987A.$$

Therefore, L = 150µH which is obtained from the inductor selection graph of LM2577-ADJ [22] based on the values of E*T and IIND, DC.

(2) Design of Rc, Cc (compensation network) and Cout

$$R_C \leq \frac{750\times I_{L(max)}\times V^2{}_{OUT}}{V^2{}_{IN(min)}}. \quad (3.4)$$

$$R_C \leq \frac{750\times 600mA\times 7^2}{5^2}.$$

$$R_C \leq 882\Omega.$$

Standard value of resistor value 1kΩ is used.

$$C_{OUT} \geq \frac{0.19\times L\times R_C\times I_{L(max)}}{V_{IN(min)}\times V_{OUT}}. \quad (3.5)$$

$$C_{OUT} \geq \frac{0.19\times 150\mu H\times 882\Omega\times 600mA}{5V\times 7V}.$$

$$C_{OUT} \geq 430.9\mu F.$$

Standard value of capacitor value 470µF is used.

$$C_C \geq \frac{58.5\times V^2{}_{OUT}\times C_{OUT}}{R^2{}_C\times V_{IN(min)}}. \quad (3.6)$$

$$C_C \geq \frac{58.5\times 7^2\times 430.9\mu F}{(882\Omega)^2\times 5V}.$$

$$C_C \geq 0.317\mu F.$$

Standard value of capacitor value 0.33µF is used.
(3) Design of R1 and R2

$$V_{OUT} = 1.23V\left(1+\frac{R1}{R2}\right). \quad (3.7)$$

By rearranging eqn. (3.7),

$$\frac{R1}{R2} = \frac{V_{OUT}}{1.23V} - 1$$

$$\frac{R1}{R2} = \frac{7V}{1.23V} - 1 = 4.69.$$

If R2 = 1.5kΩ, then
R1 = 4.69 × R2 = 4.69 × 1.5kΩ = 7.03kΩ. (Variable 10kΩ).

H. LCD

LCD shown in Figure 18 is a passive light source device which uses liquid crystal as an illuminator developed by Hitachi as HD44780 display driver controller. LCD overcomes previous seven segment display by power usage, size, interface flexibility, programming etc. which suits with all the controller family. LCD is divided into three section.

- ✓ PCB where drivers and connections will be there.
- ✓ Backplane to reflect the light and hold the crystal in pocket.
- ✓ Glass plane where user can view the information.

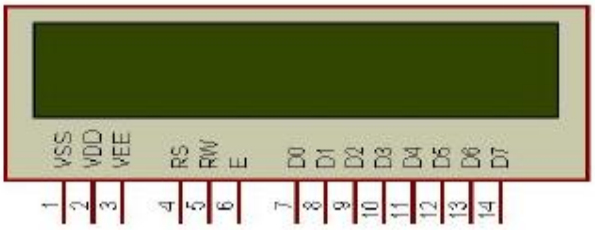

Figure 18: Pin Details of LCD 16x2

LCD provides visible information for N number of applications. Generally LCD comes in 16x1, 16x2 or 20x4 display size format. 16x2 LCD is used to display various sensor status and warning messages. 16x2 represents 2 line 32 characters in total. User can interface with display using 16 pins where seven pins are data lines, three are control lines and the rest are power supply connection. To address specific location on first line 0x80 - 0x8F, for second line location 0xC0 – 0xCF are the commands. To view information during the time of dark additional light source called as back light is used.

VI. SOFTWARE REQUIREMENT

A. TI-RTOS

TI-RTOS is an on-going working framework that empowers quicker improvement by taking out the requirement for engineers to develop and keep up framework programming, for example, schedulers, protocol stacks, control administration structures and drivers. It is furnished with full C source code, requires no runtime environment expenses. TI-RTOS is upheld specifically by TI. TI-RTOS shown in Figure 19 scales from a small footprint, on-going pre-emptive multitasking portion to an entire RTOS with extra middleware parts including a power hub, TCP/IP and USB stacks, a FAT format and peripheral drivers, permitting designers to concentrate on distinguishing their application. It gives a steady implanted programming stage over TI's implanted handling portfolio, making it simple to port existing applications to the most recent peripherals.

The TI-RTOS Kernel is comprised of various discrete parts, called modules. Every module can give access by means of API, can be separately configured. For instance, framework

semaphores are provided by module in TI-RTOS with user developed code for ready, pending and deleted while embedded program runs.

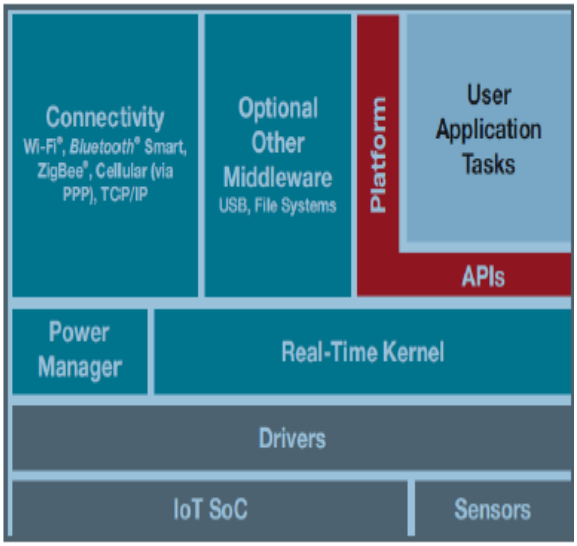

Figure 19: RTOS Layers

Threading: Kernel gives full and few distinct sorts of strings in an inserted framework. Hardware Interrupt (Hwi): bolster strings started by equipment interfere. Software Interrupt (Swi): organized to be like Hwi, yet permit handling to be conceded until after equipment hinder has finished.

Memory management: This gives tooling to set up an inserted framework's memory guide furthermore to permit memory cradles to be designated and de-allocated while the framework runs. The kind of memory chief utilized amid runtime is really configurable so that memory discontinuity can be minimized if essential.

On-going debugging: This module permits it to give data about how the framework is executing. This incorporates how distinctive strings are stacking the CPU after some time and logging occasions as they happen in both the framework application and also inside the TI-RTOS kernel itself.

B. AMAZON WEB SERVICES

This is utilized as a part for server operation with committed port as client can get to the data from the application at whatever time and module associated with the peripherals are connected to Amazon server with dedicated IP and port forward which does the remote design of the framework.

C. MQTT PROTOCOL

As we most likely know, the focal point of WSN is a communication itself. In the present day internet there is an awesome number of traditions and structures used to complete communication channels. This arrangement is profoundly diminished in a WSN circumstance. A great part of the time, "WSN" that are talking with each other have compelled resources as follows; processor, memory and battery. Fortunately, there are answers for those limited necessities. One of them is MQTT a lightweight network protocol.

MQTT remains for Message Queuing Telemetry Transport. It publish/subscribe to a QoS and light weight protocol, specifically compelled for the radio which uses very low bandwidth for transferring data with idleness at its high with query based systems. The plan for minimizing arranged capacity for transferring the data with prerequisites libraries while guarantee enhanced process with quality at its level of affirmation of protocol.

- ✓ Subscribe to corresponding topic that will be published.
- ✓ Publish corresponding topic that is subscribed.
- ✓ Receive message from the publisher.
- ✓ Publish the message to subscriber.

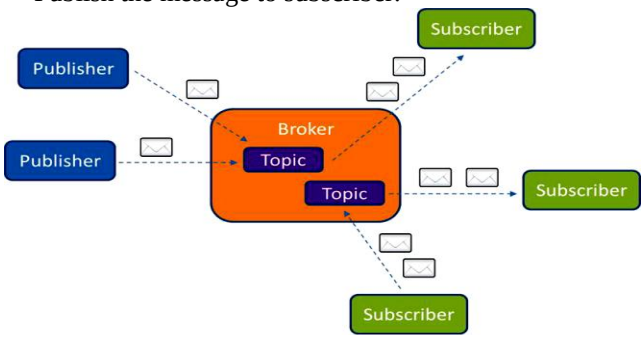

Figure 20: MQTT Flow

A MQTT flow shown in Figure 20 is partitioned into four segments as follows; association, validation, correspondence and end. Host begins by making a TCP/IP link with the client by either utilizing a standard port or a custom port characterized by the representing IP. While associating, perceive that the server may proceed with an old session if included with a re-utilized customer character.

MQTT gives the run on QoS levels for message situated in broker. Despite the fact that TCP/IP gives ensured information protocol, information loss can happen if a TCP link disconnects and messages that are transmitted is lost. Along these lines MQTT includes three characteristics of administration levels on TCP top as shown in Figure 21.

QoS 0 (at-most once): In this service guarantee will be given for the message that will be received.

QoS 1 (at-least once): In this level message will be received with its duplicate.

QoS 2 (exactly once): It is the combination of 0 and 1 level.

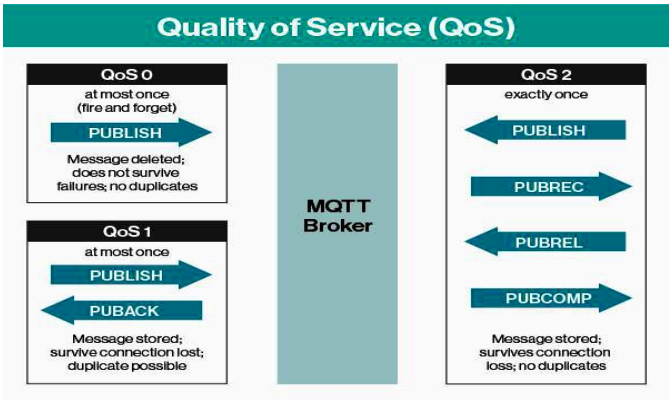

Figure 21: MQTT QoS LeveL

VII. RESULTS AND DISCUSSION

Figure 22 shows the Prototype of solar powered WSN for pipeline monitoring system. The overall system with peripherals interfaced to carry out specific operation. Automation is done to send and receive messages in the format of topic with an android app developed for engineers to monitor the status of the station. This is done by automatically subscribing and publishing for the corresponding topics. This module is connected with energy harvester using mono crystalline PV module with a Dc-Dc converter and dedicated power bank. Message queuing and telemetry transporting protocol is used between node and master.

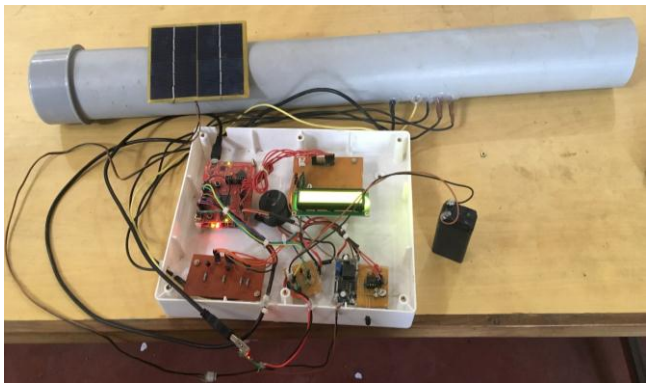

Figure 22: Variation of Temperature with respect to Flow

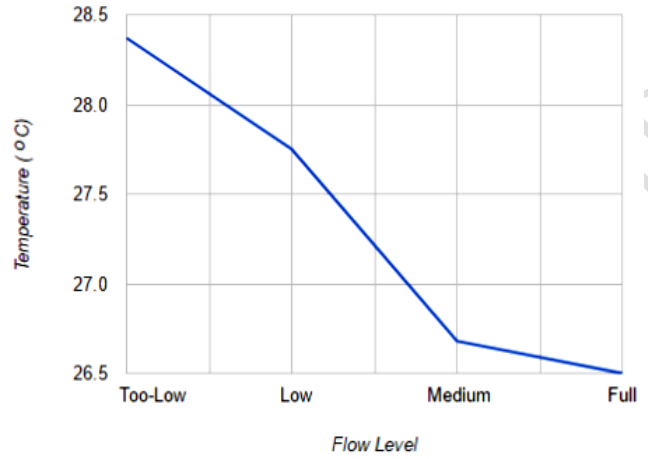

Figure 23: Variation of Temperature with respect to Flow

Figure 24 shows the output voltage from PV module recorded over a span of ten hours on a particular day with readings taken once in half an hour. The peak voltage obtained is 6.6V and the minimum voltage is 5 V. The input voltage range of 5–6.6 V is adequate for charging of battery.

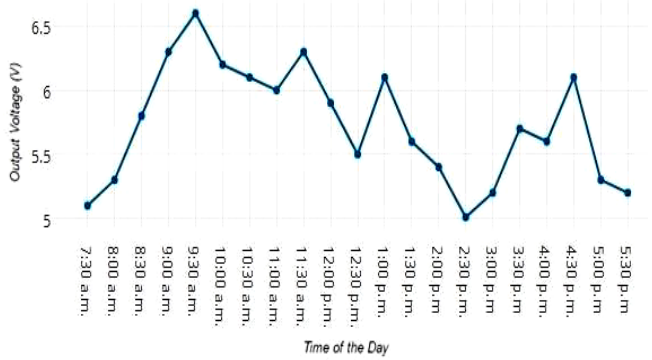

Figure 24: Output Voltage of Solar Panel v/s Time of the Day

Figure 25 shows Vout v/s Vin, Vout v/s output current for Vin = 5 V and efficiency v/s output current graphs for circuit of dc-dc converter.

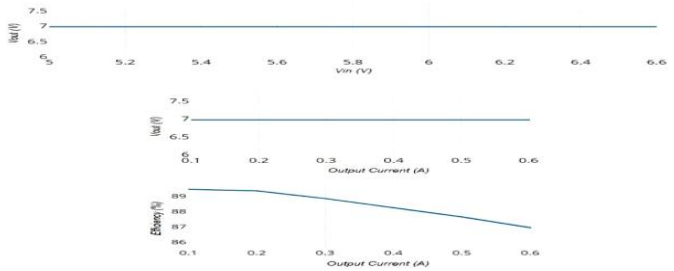

Figure 25: Output Waveforms of DC-DC Converter

VIII. CONCLUSION

Wired stations with OFC need more than three qualified personnel to assess the system and need to be present in the allotted DCS. Due to this oil Corporation is bearing more financial burden. Multiple remote stations with existing framework does not have proper person to monitor and process. If a dedicated person is allotted, it is difficult to provide transportation in such harsh condition. In case of any emergency, time taken by the team to reach the spot in this environmental condition will be delayed which will cause huge loss and company need to bear all the expense that are in-occurring repeatedly. For this reason a node is designed so that any variations in the system is identified and will take necessary action to prevent any destruction. The main thing is WSN need to harvest energy of its own. In case of any failure in harvesting, system will operate by enabling its secured mode. It is called as sleep and wakeup strategy which plays a very important role in providing the power to the system for continuous operation. Second part is system sends information to the field engineers which provides status of the station. The main purpose of using MQTT protocol is to maintain constant connection using low bandwidth with QoS level 3. Because of this, it is a user friendly monitoring and communication system for oil Corporation.

IX. FUTURE ENHANCEMENT

All the WSN system developed in the present prototype provides the enhanced features and the limitation are nullified with respect to earlier solution that were available to transfer data between the master and node. There are multiple enhancements which has scope for improvement, some of the features such as

- ✓ Hop based node-to-node communication
- ✓ Ask and execute algorithm
- ✓ Alternate energy harvesting in case of solar failure
- ✓ Self-diagnosing and information processing in case of any node failure
- ✓ On-board log storage in case of communication failure

REFERENCES

[1] Do-Hun Kang, Min-Sung Park, Hyoung-Sub Kim, Da-young Kim, Sang-Hui Kim, Hyeon-Ju Son, Sang-Gon Lee "Room Temperature Control and Fire Alarm/Suppression IoT Service Using MQTT on AWS", 978-1-5090-5140-3/17/$31.00 ©2017 IEEE.
[2] Shayama Subair and Lizy Abraham, "Analysis of Different Temperature Sensors for Space Application", International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 6, ISSN 2348 – 7968, August 2014, pp. 35-40.
[3] Gary L. Burkhardt, Alfred E. Crouch, "Realtime Monitoring of Pipelines for third party contract", South West Institute – December 2003.
[4] K R Anupama, Nishad Kamdar, Santosh Kumar Kamalampet, Dhruv Vyas, Siddharth Sahu, Supan Shah, "A wireless sensor network based pipeline monitoring system", International Conference on Signal Processing and Integrated Networks (SPIN), IEEE Conference Publications, 2014, pp. 412- 419.
[5] Ganeriwal S., Kumar R., and Srivastava, M. B., "Timing-Sync Protocol for Sensor Networks", The First ACM Conference on Embedded Networked Sensor System (SenSys), p. 138–149, November 2003.
[6] Jianning Ding, Junwen Wang, Ningyi Yuan, Qiaoling Pan, "The Monitoring System of Leakage Accidents in Crude Oil Pipeline based on ZigBee Technology", Second International Conference on Mechanic Automation and Control Engineering, IEEE Conference Publications, 2011, pp. 1774-1777.
[7] Imad Jawhar, Nader Mohamed, Khaled Shuaib, "A framework for pipeline infrastructure monitoring using wireless sensor networks" Wireless Telecommunications Symposium, IEEE Conference Publications, 2007.
[8] Specifications of the bluetooth system - version 1.2. 2003.
[9] Ali M. Sadeghioon, Nicole Metje, David N. Chapman and Carl J. Anthony "SmartPipes: Smart Wireless Sensor Networks for Leak Detection in Water Pipelines", J. Sens. Actuator Netw. 2014, 3, 64-78.
[10] D.Jeevani, M.Balajee, "Effective Device Management for Internet of Things", International Journal of Engineering and Information Systems, Vol. 1 Issue 8, October – 2017, Pages: 172-181.
[11] Meenu muraleedharan, Merin K J, Nijisha Jose, Dr.Vince Paul "Survey on device management in IoT", JETIR (ISSN-2349-5162), October 2016, Volume 3, Issue 10
[12] P. Kamalinejad, C. Mahapatra, Z. Sheng, S. Mirabbasi, C. M. L. Victor, and Y. L. Guan, "Wireless energy harvesting for the internet of things", IEEE Communications Magazine, vol. 53, pp. 102 - 108, 2015.
[13] Adnant Jushi, Alain Pegatoquet, Trong Nhan Le, "Wind Energy Harvesting for Autonomous Wireless Sensor Networks", Euromicro Conference on Digital System Design (DSD), IEEE Conference Publications, 2016, pp. 301-308.
[14] A.Pietrelli, A. Micangeli, V. Ferrara, A. Raffi, "Wireless Sensor Network Powered by a Terrestrial Microbial Fuel Cell as a Sustainable Land Monitoring Energy System," Sustainability, 2014, 7263.
[15] Andrea Pietrelli, Vincenzo Ferrara, Andrea Micangeli, Lidieth Uribe, "Efficient Energy Harvesting for Microbial Fuel Cell dedicated to Wireless Sensor Network", XVIII AISEM Annual Conference, IEEE Conference Publications, 2015.
[16] Apolinar González, Raul Aquino, Walter Mata, Alberto Ochoa, Pedro Saldana and Arthur Edwards, "Open-WiSe: A Solar Powered Wireless Sensor Network Platform", Sensors, 2012, vol. 12, pp. 8204-8217.
[17] Augustine C. Azubogu, Victor E. Idigo, Schola U. Nnebe, Obinna S. Oguejiofor, and Simon E., "Wireless Sensor Networks for Long Distance Pipeline Monitoring", World Academy of Science, Engineering and Technology, International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering Vol:7, No:3, 2013.
[18] https://www.maximintegrated.com/en/products/analog/sensorsandsensorinterface/DS18B20.html to know about DS18B20
[19] http://www.ibm.com/developerworks/community/blogs/5things/entry/5things to know About mqtt the protocol for internet of things
[20] H. Takhedmit, W. Haboubi, O. Picon, and L. Cirio, "Harvesting ambient radio frequency electromagnetic energy", in Sensors, Energy Harvesting, Wireless Network & Smart Objects Conference, 2015.
[21] X. Y. Li, Y. J. Wang and Y. Wang, "Complexity of Data Collection, Aggregation, and Selection for Wireless Sensor Networks," IEEE Transactions on Computers, February 2010.
[22] http://www.ti.com/lit/pdf/slus216 to know about the design of dc-dc converter circuit.