Iot Based Smart Controlled Inverter

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Abstract *- Nowadays Internet of Things (IoT) is becoming more popular and embedded in our day to day life because of its smartness and increased connectivity. IoT Trends can be easily integrated into energy management which will make the life of people more comfortable and easier. One of the most immense methods of generating electricity without emission or noise is through PV solar electricity by converting abundant sunlight to electrical energy. Solar photovoltaic (PV) systems require low maintenance and no pollution discharge. However, the intermittency and variability nature of renewable energy sources may result into power system instability if intelligent interface is not provided. A power electronics inverter system should have a digital design, robust software facilities and a two-way communications ability in order to make the system intelligent. Hence Eco-friendly IoT based smart controlled inverter, is proposed in the paper to increase human comfort with Wi-Fi technology to engage in a two way communication with the user. The user can control the connected load as well as monitor the load current & status of the connected devices through Mobile Application or Web URL. In which the user can connect / disconnect the devices based on the requirement choice. The load current is measured by current sensor and the acquired data is transferred to the Web URL through Wi-Fi module. The remote node can control the connected loads again via the same Wi-Fi module through internet. This work uses the ESP8266 Node MCU Wi-Fi module and ACS 712 Hall effect current sensor to monitor and control the loads anywhere within the Wi-Fi limit.*

Keywords - *Charge controller, DC Load, Inverter, IoT, Node MCU, PV, Wi-Fi*

I. INTRODUCTION

Internet of Things (IoT) may be a hot topic in the industry but it's not a new concept. IoT refers to a network comprised of physical objects capable of gathering and sharing electronic information. It includes a wide variety of "smart" devices, from industrial machines that transmit data about the production process to sensors that track information about the human body [12]. These sensors can use various types of local area connections such as RFID, NFC, Wi-Fi, Bluetooth, and Zigbee. Sensors can also have wide area connectivity such as GSM, GPRS, 4G, and LTE. Out of the potential Internet of Things application areas, Smart Cities (and regions), Smart Car and mobility, Smart Home and assisted living, Smart Industries, Public safety, Energy & environmental protection, Agriculture and Tourism as part of a future IoT Ecosystem have acquired high attention [6].

Similarly, in recent times, there has been continuous increase in energy consumption which has also led to the increase of renewable energy production. There are different sources of energy currently in use but unfortunately, most of the energy sources come from conventional fossil fuels. The environmental impacts of fossil fuels such as oil, coal and gas are very enormous and hazardous. Apart from contaminating the air, polluting and harming the environment, it has been identified as the main culprit in increasing greenhouse gases (GHGs) in the atmosphere, which is causing global climate change. One of the most immense methods of generating electricity without emissions or noise is through PV solar electricity by converting abundant sunlight to electrical energy [8]. Solar photovoltaic (PV) systems are used for several applications since the maintenance required is low and no pollution discharged. However, the intermittency and variability nature of renewable energy sources may result into power system instability if intelligent interface is not provided.

A power electronics inverter system should have a digital design, robust software facilities and a two-way communications ability in order to make the system intelligent. The system typically comprises of a reliable, robust and proficient silicon-based hardware, which can be controlled by an adaptable software environment by integrating a control structure capable of advanced performance monitoring. The intelligent or smart interface can be developed by employing Power electronics technology. Therefore, in order to effectively achieve reliability with the power output, a power electronics interface system such as a smart inverter system is required [8].

Hence in the work, Eco-friendly IoT based smart controlled inverter is proposed to control the various combination of load in the home / Industry on user choice basis intellectually through Wi-Fi. The proposed system is designed and implemented using ESP 8266 Node MCU Wi-Fi module and ACS 712 current sensor and tested using DC loads. The paper is organised by briefing the related existing works with identifying the gaps in section 2, detailing the proposed system architecture and its development in section 3, implementation of the proposed work in section 4 and conclusion in section 5. The following section will brief the related existing works of the proposed system with identifying the gaps in them.

II. LITERATURE SURVEY

The increasing energy demand and pollution caused by the rapidly depleting fossil fuels have now given way to the use of renewable sources to meet energy demands [9]. Among the renewable energy sources, high interest is on the solar energy which generates electricity using PV (Photo Voltaic) modules. The fact that there is a need for more efficient usage of renewable energy sources and solar energy happens to be one of them the smart inverters are need of the day. The solar energy can be used to charge the batteries during day time and the stored energy in the battery can be used when solar energy is not present.

The Smart inverters are generally as inverters which are charged through solar energy and which can perform solar tracking [7]. The authors have used stepper motors to perform the solar tracking using the MQTT algorithm. However smart inverters can also be looked upon as inverters with bidirectional communication with the user and other stakeholders in the system. The work explored the possibility by introducing interaction between the user and the inverter via IoT.

Residential houses were incorporated with a WSN system whose nodes aggregated the energy consumption data of different appliances in the house and presented it to the user for analysing [3]. In the work authors considered a crucial situation where the user should be aware of his energy consumption i.e in the event of a power failure, and acknowledged the fact that they have the inverter’s limited resource in the form of its battery in order to meet energy needs. Hence the authors displayed to the user how long user can run their loads with the existing battery voltage.

A circuit consisting of IC LM3914 and LEDs to indicate the battery voltage level of an inverter was proposed in [12]. The battery voltage level was used to drive the LEDs via a regulator. Depending upon which of the 10 LEDs was glowing, the user could infer the amount of battery voltage left. This work improved upon the aforesaid idea by displaying the battery voltage by directly sensing it using a microcontroller, thus making it more accurate. The same voltage is displayed to the user via a mobile app along with the run-time of the loads.

A smart inverter integrating with raspberry pi which makes smart home was proposed in [1]. In this work, a bi-level (Supervisory-Local) PV based micro grid configuration was proposed for low power residential applications. In the supervisory level a long-term control scheme is assigned to define the set points for local controllers. The local level is mainly formed from a set of controllers which are basically responsible to control the power electronic interfaces and converters. Within the supervisory level a dynamic price scheduling framework with load and solar energy forecasting is implemented using time series-based regression technique. In the local level, adaptive double mode controllers are developed to realize intelligent inverters with smart grid-tied (GT) capabilities and smooth transition between GT and stand-alone modes.

The implementation of a smart inverter was proposed in [8] i.e a solar charged inverter that uses Wi-Fi technology to engage in a two way communication with the user, informing the user of both, the inverter as well as run time of the loads which the user chooses to run. Furthermore, wireless control of loads is implemented to increase human comfort. The project deals about the improvement of the reliability of power supply for the high load demand and mainly for the critical load. Mostly power demand will be met with the power supply generation with EB supply and the combined battery inverter set. But in that project renewable energy from PV cell is majorly utilized to meet the power demand along with the EB supply and battery inverter combination. In a day, climate is changes continually so, that time power output in PV cells also changes. Here the authors have a controlling and monitoring of the power output is maintained for the stable output power in all atmospheric conditions to loads. Controlling of the input source connection with the load has been done with microcontroller with help of IoT.

The designing of devices that have built-in capability to measure and report the energy use or receive control input over the network was focussed by Arati Kurde and Kulkarni. This study will help in creating energy awareness devices. Current sensor measures the current flowing through device then controller performs necessary calculations on the data and puts that data on the internet. By measuring current and voltage, energy consumption can be analysed, to make the world smarter place and make better decisions using Internet of Things.

In general remote monitoring systems have to fetch, analyse, transmit, manage and feedback the remote information [5], by utilizing the most advanced science and technology field of communication technology and other areas. It also merges comprehensive usage of instrumentation, electronic technology and computer software.

Prevalent monitoring PV system approaches present poses some problems like low automaticity and poor real-time. These problems can be averted with an efficient remote environment information monitoring and controlling system. This system should include automatic diagnosis techniques in the PV station.

A predictive maintenance which includes localization and definition of related faults and failures in a PV system is very important. Concentration has been given on the most widely used ones. Remote monitoring and control of PV system based on Zigbee technology as in [10], is proven inefficient in large scale because it can't face up huge distance.

Wi-fi technology is also used for remote monitoring and control of PV system for domestic applications. Wi-Fi (IEEE 802.11g) is chosen as it operates at 2.4GHz and offer high data rate of about 54Mbps in contrast to ZigBee (250Kbps). But this solution is suitable for micro grid network architecture.

At present, a number of PV monitoring system has been put into operation. These systems often use wireless public networks such as GSM or other wireless communication networks for data transmission. But there are problems of high operation and maintenance cost which restrict the development of monitoring system and ultimately hinder the process of efficient generation monitoring in real time. In the paper [11], a novel remote monitoring and control of PV system based on IoT has investigated.

In [14], a new cost effective methodology based on IoT was implemented to remotely monitor a solar photovoltaic plant for performance evaluation. This will facilitate preventive maintenance, fault detection, historical analysis of the plant in addition to real time monitoring.

From the literature survey, it is observed that IoT based smart inverters monitoring system were designed various controllers such as arduino uno, etc and without considering Wi-Fi. Those controllers may not be power efficient as well as those works were not implemented in Wi-Fi. Hence in the proposed work, IoT based smart inverter monitoring and controlling system is going to be designed with Wi-Fi such as ESP8266 (Wi-Fi module), it is cheap, easily programmed to send and receive the data. The following section will elaborate the architecture of the proposed system.

III. PROPOSED IOT BASED SMART CONTROLLED INVERTER

The proposed IoT based smart controlled inverter is implemented by interconnecting Solar PV panel, charge controller, inverter, battery, Wi-Fi Module and current sensor with different types of loads connected through a 4 channel relay unit.

The Fig.1 shows the functional architecture of the proposed IoT based smart controlled inverter. In which the PV panel acts as the source of voltage which is been stored in the battery through the inverter. The Voltage of the battery, after being reduced using a voltage divider circuit, is given to one of the ADC pins of the microcontroller. This digital value of the source voltage is used to perform necessary calculations to display the time for which the loads can run. ESP8266 is connected to the microcontroller to transmit and receive messages using the Transmit and Receive pins of the controller. When a user sends a message to the Wi-Fi module ESP8266, it sends the same to the controller which is programmed to accept the message and compare it with a pre-defined string. Fig.1 illustrates functional architecture of the Proposed IoT based smart controlled Inverter.

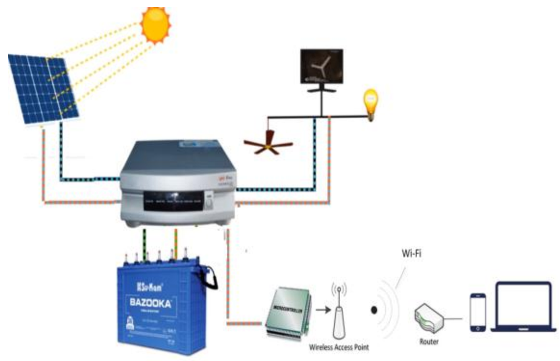

Fig 1: Functional Architecture of the Proposed IoT Based Smart Controlled Inverter

Fig. 2 is detailing the block diagram of the proposed IoT based smart controlled Inverter.

- **Steps in Implementing IoT based Smart Controlled Inverter:**

Step 1: PV panel converts the Green Solar Energy into Electrical Energy.

Step 2:Received Energy will be stored in the battery through Charge Controller in the inverter.

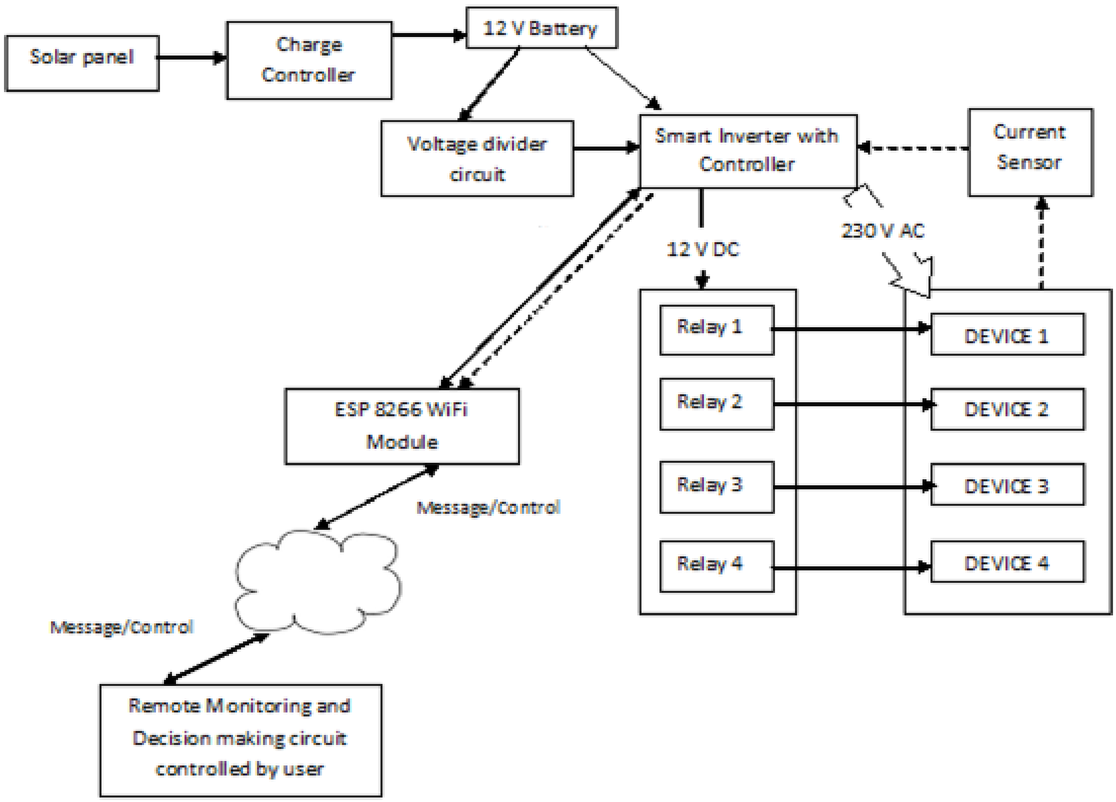

Fig 2: Block Diagram of the proposed IoT based smart controlled inverter.

Step 3:The inverter will convert the DC to AC and supplies to the different Load through the 4 channel relay circuit.

Step 4:Current sensor ACS712 senses the load current continuously and give the details through Wi-Fi module to the mobile device of user.

Step 5:If the load current level goes above the threshold level the user can disconnect and control the unwanted loads using Android app via Wi-Fi communication.

Step 6:When the load current level goes below the threshold value, the entire load / required loads will be connected using Android app / mobile URL site ON-OFF control via Node MCU Wi-Fi communication.

The above Flow chart in Fig. 3 explains the principle of operation of proposed IoT based Smart Controlled Inverter.

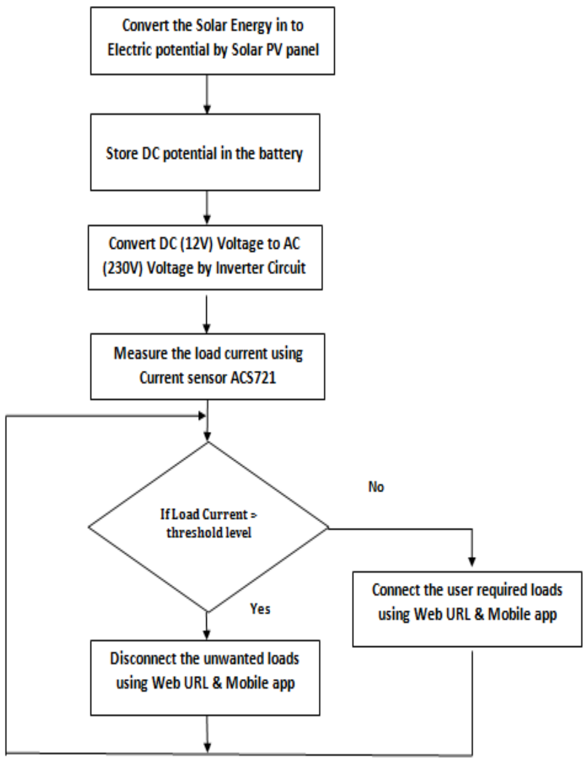

Fig 3: Functional Flow Chart of the Proposed IoT based Smart Controlled Inverter

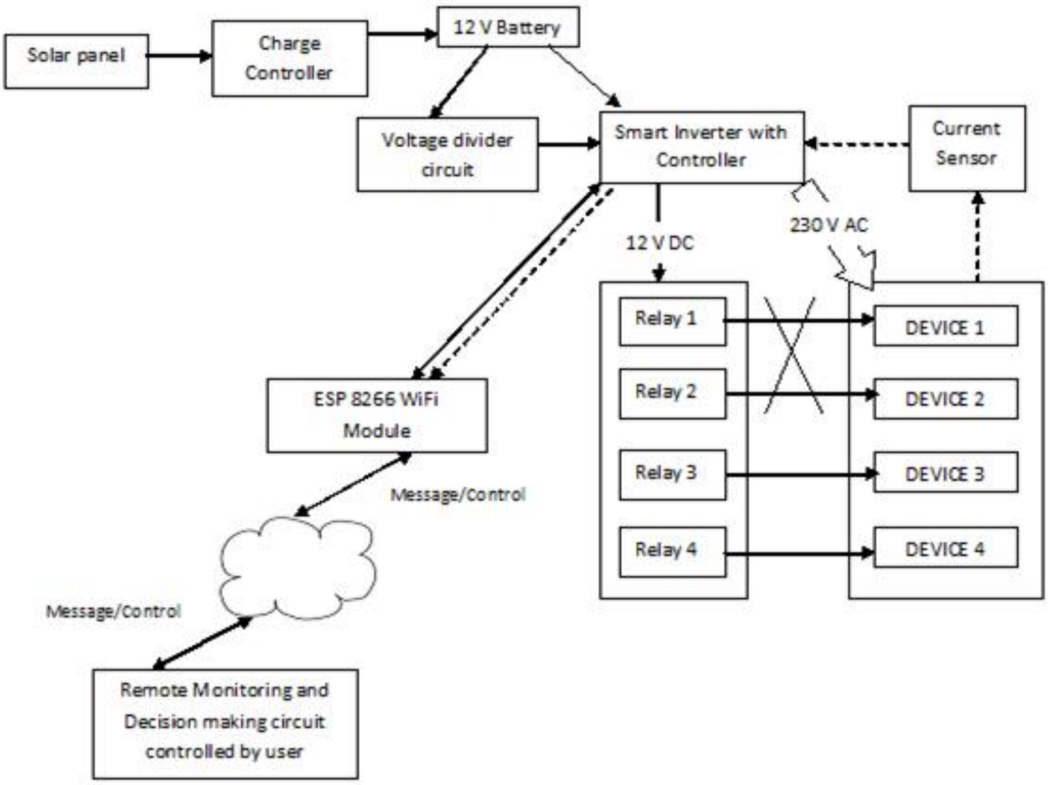

Fig 4: Sequential controlling of two loads by the Proposed IoT Based Smart Controlled Inverter

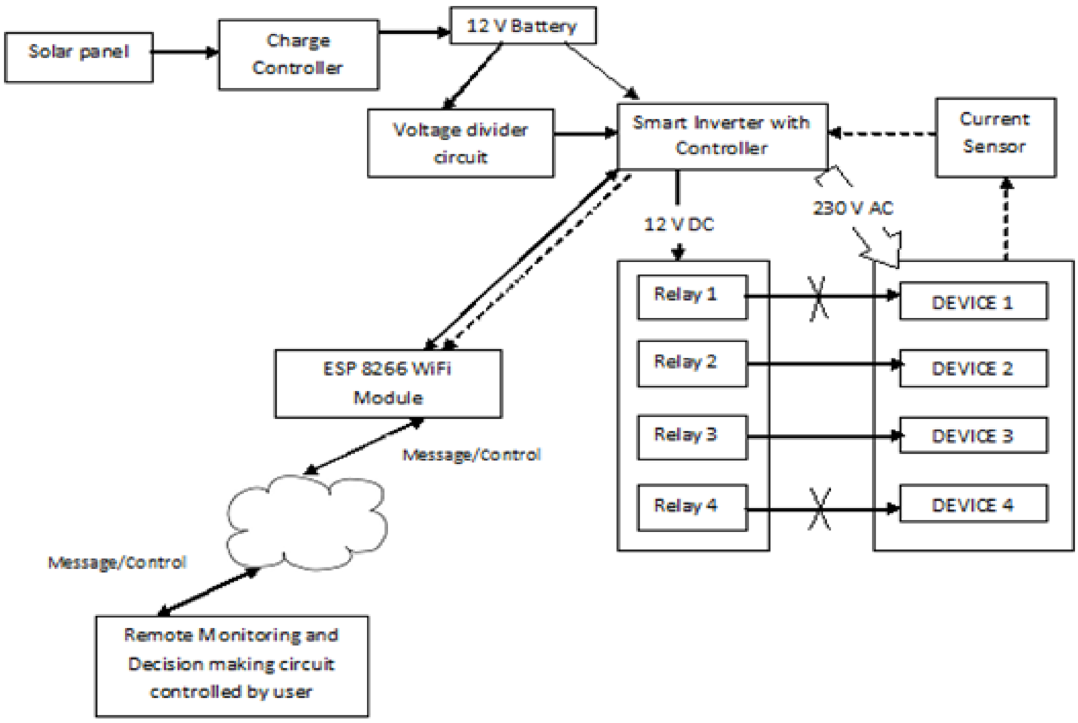

Fig 5: Random controlling of two loads by the Proposed IoT Based Smart Controlled Inverter

Fig. 4 illustrates the scenario of the proposed work when the Load current above the threshold value, user can control the loads by connecting / disconnecting sequentially through Web URL/ mobile application.

Fig. 5 Explore the scenario of the proposed work when the load current goes below the threshold level then, the remote user can switching ON the devices intellectually by the mobile app or Web URL through Wi-Fi Internet. Here the user choice loads are device 1 and 4, randomly. The user can see the present load current variation in the Mobile Application / Web URL.

IV. IMPLEMENTATION RESULTS AND DISCUSSION

The physical setup showed in the Fig. 5 illustrates the acquisition of green DC potential from 10w peak PV panel. The physical setup showed in the following Fig. 6 and Fig. 7 illustrate the storage of acquired green DC potential in Battery through charge controller and connecting load.

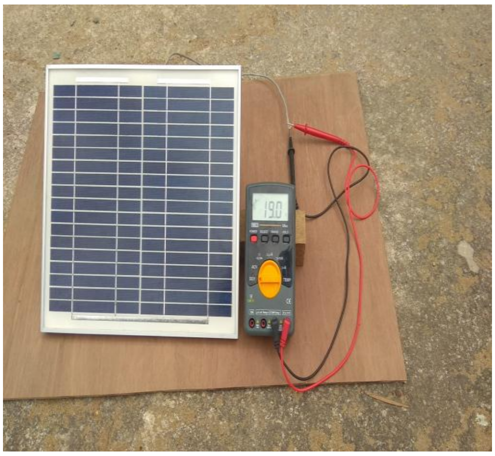

Fig 5: Acquisition of Green DC potential from 10w peak PV panel

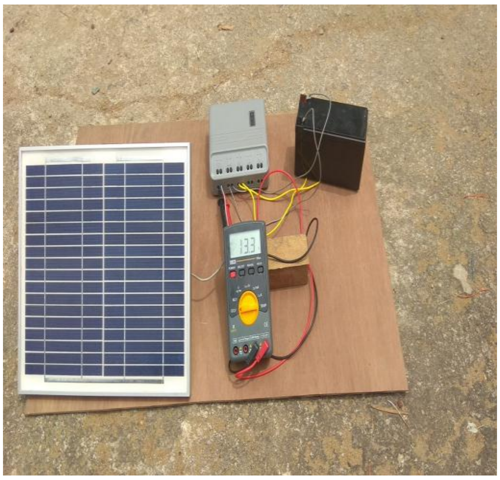

Fig 6: Charging the Battery

Fig 7: Connecting DC load with Battery

The ESP8266 Wi-Fi Module is configured with other wireless smart devices such a Smart phones. through the laptop in which by using the Real Term serial capture program 2.0.0.70. AT commands are executed to control the devices and connected load.. The following flow chart in Fig. 8 Shows the steps involved in Wi-Fi module configuration.

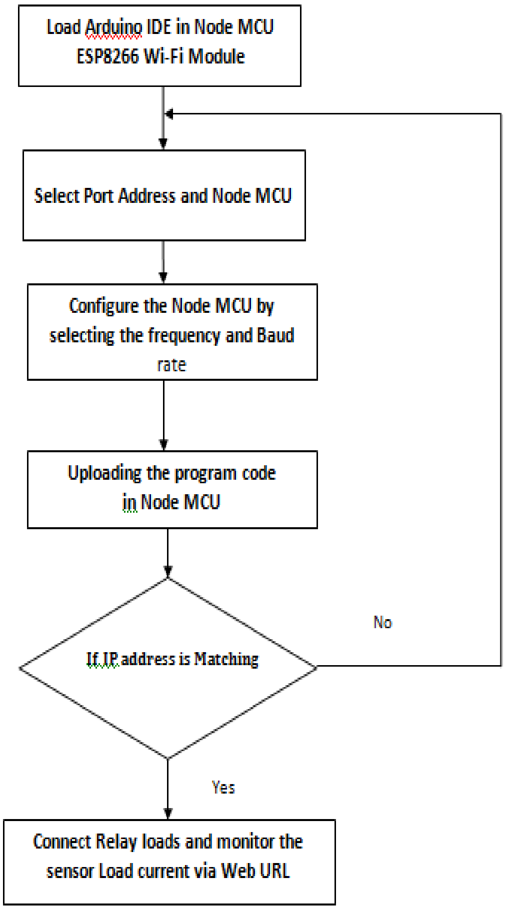

Fig. 8 Flow Chart of Wi-Fi module configuration

Fig. 9 shows the real experimental setup of interfacing current sensor with load represented by Rheostat. ACS712 current sensor operates from 5V and outputs analog voltage proportional to current measured on the sensing terminals, and ADC of the Wi-Fi module read the values. In which the output voltage is measured by the help of multi meter. When the current sensor connects the DC load (VCC: +5V) and the output voltage without any load is VCC/2 it means around 2.5V. When DC load takes current, the output voltage will deviate from 2.5V to either 0V or 5V depending on polarity of sensing load.

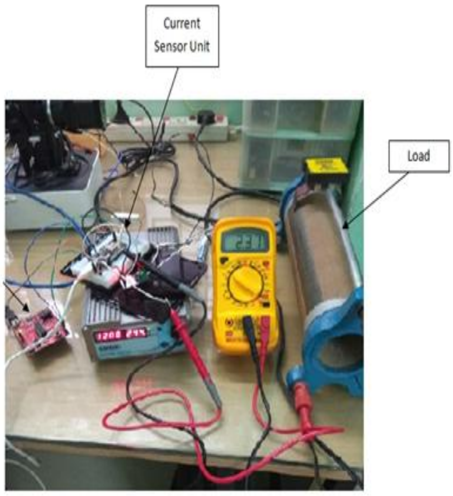

Fig 9: Load current Measurement using Current

ACS712 current sensor operates from 5V and outputs analog voltage proportional to current measured on the sensing terminals. A microcontroller ADC can be used to read the values. Sensing terminal can even measure current for loads operating at high voltages like 230V AC mains while output sensed voltage is isolated from measuring part. ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems.

The output of the device has positive slope when an increasing current flows through the copper conduction path. The ACS712 device comes in three variants, providing current range of±5A (ACS712-05B), ±20A (ACS712-20B), and ±30A (ACS712-30A). The ACS712-05B can measure current up to ±5A and provides output sensitivity of 185mV/A (at +5V power supply), which means for every 1A increase in the current through the conduction terminals in positive direction, the output voltage also rises by 185 mV. The sensitivities of 20A and 30A versions are 100 mV/A and 66 mV/A, respectively. At zero current, the output voltage is half of the supply voltage (VCC/2). It should be noted that the ACS712 provides ratio metric output, which means the zero current output and the device sensitivity are both proportional to the supply voltage, VCC. This feature is particularly useful when using the ACS712 with an analog-to-digital converter. The precision of any A/D conversion depends upon the stability of the reference voltage used in the ADC operation. In most microcontroller circuits, the reference voltage for A/D conversion is the supply voltage itself. So, if the supply voltage is not stable, the ADC measurements may not be precise and accurate. However, if the reference voltage of ADC is same as the supply voltage of ACS712, then the ratiometric output of ACS712 will compensate for any error in the A/D conversion due to the fluctuation in the reference voltage.

The 4-Channel Relay interface board is used to interface and control the AC/DC loads, via connected through each relay it has needs 15-20mA Driver Current .The relays are equipped with high-current rating , AC 230Volts 5Amp ; DC30Volts 5 Amps .The standard interface can be controlled by (Arduino , 8051, AVR, PIC, DSP, ARM, ARM, MSP431, TTL logic) any one of the microcontroller. In the work, the Wi-Fi module controls the relay operation. The relay outputs status is indicated by LED's. Contact part of the independent wiring terminal is safe and reliable.

The ESP8266 is a low-cost Wi-Fi chip with full TCP/IP stack and MCU (microcontroller unit) capability Processor: L106 32-bit RISC microprocessor core based on the TensilicaXtensa Diamond Standard 106Micro running at 80 MHz. The ESP8266 Wi-Fi Module is a self contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to any Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. Each ESP8266 module comes pre-programmed with an AT command set firmware, which simply hook this up to Arduino device and get about as much Wi-Fi-ability as a Wi-Fi Shield offers. The ESP8266 module is an extremely cost effective board with a huge, and ever growing, community.

This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimal PCB area. The ESP8266 supports APSD for VoIP applications and Bluetooth co-existence interfaces; it contains a self-calibrated RF allowing it to work under all operating conditions, and requires no external RF parts. The ESP8266 is being controlled using the AT commands to get connect to the peripheral devices as either master or slave depending upon the AT commands.

The Fig. 10 illustrates the designed Web URL to control the loads from remote and the measured load current reading and status of the various loads connected.

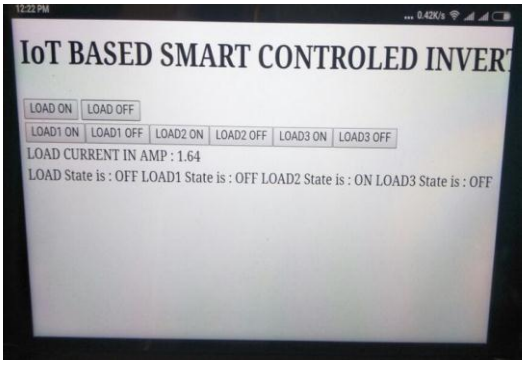

Fig 10: Web URL to control Loads showing measurements and status of the loads

Fig 11: Web URL based remote control of equal three AC loads

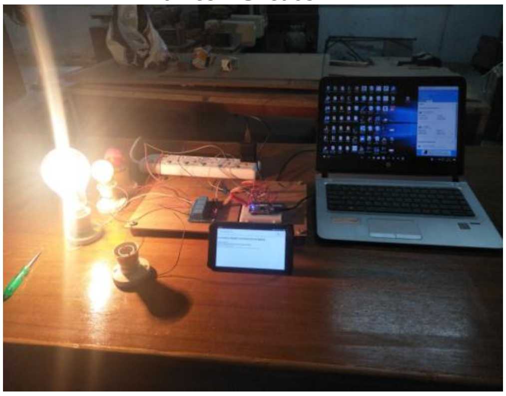

Fig 12: Web URL based remote control of unequal two AC loads

Fig. 11 and Fig. 12 illustrate the Web URL based remote control of AC loads with equal three loads and the two unequal loads using the proposed IoT based smart controlled inverter using Web URL.

V. CONCLUSIONS

IoT based Smart controlled inverter is being implemented by adapting an existing inverter with bidirectional communication with the user by power management system. Based on the priorities, anyone can control wirelessly loads at the time of power cut, simultaneously they can monitor the load current of the inverter. This prototype gives us a deep insight into working of a self sufficient and reliable system for monitoring and controlling loads using existing load current. The green energy system requires only initial stage investment in solar panel and the smart controlled inverter system is developed at low cost. A consumer generates enough energy for oneself and uses it accordingly with an environment friendly system. Hence in the work, Eco-friendly IoT based smart controlled inverter is proposed to control the various combination of load in the home or Industry on user choice basis intellectually through Wi-Fi.

REFERENCES

[1] A. Megha Joshi, S. Kavyashree, “*IoT Based Smart Inverter Using Raspberry PI*”, International Journal of Latest Technology in Engineering, Management & Applied Science, 2017

[2] AchimWoyte, MauricioRichter, David Moser,StefanMau, NilsReich, UlrikeJahn “ *Monitoring Of Photovoltaic Systems , Good Practices And Systematic Analysis*”, 28th European PV Solar, 2016

[3] Aoi Hashizume, Tandanori Mizuno and Hiroshi Mineo, “*Energy Monitoring System using Sensor Networks in Residential Houses,*” in *proc. of 26th IEEE International Conference on Advance Information Networking and Application Workshop*, June 2012.

[4] Byeongkwan Kang, SunghoiPark,Tacklim Lee, and Sehyun ParkChung, “ *IoT-based Monitoring System using Tri-level Context Making Model for Smart Home Services”*, in *proc. of IEEE International Conference on Consumer Electronics,* 2015

[5] Chen Peijiang, Jiang Xuehua, “*Design and Implementation of Remote Monitoring System Based on GSM*”, in *proc.of IEEE Pacific-Asia Workshop on Computational Intelligence and Industrial Application,* 2008

[6] G.A. Rathy, and P.Sivasankar, “*IoT based Classroom Automation using Zigbee*”, International Journal of Innovative Science, Engineering & Technology, Vol. 6 Issue 3, March 2019, pp.98-102

[7] H.Divya .“*Solar smart inverter: A novel design using multi level topology and pulse width modulation with load detection.*”, International Journal of Engineering Research & Technology, 2015.

[8] N. Santhoshkumar, B.Sasikumar, “*IoT BASED SMART INVERTER*”, International Journal of Advanced Science and Engineering Research, 2017.

[9] O.I. Adekola, A. K. Raji, “*Functionalities of smart inverter system for grid-connected applications*”. in *proc. of International Conference Industrial and Commercial Use of Energy,* 2015

[10] Oussama BEN BELGITH, Lasaad SBITA, “*Remote GSM module monitoring and Photovoltaic System control*”, in *proc. of First International Conference on Green Energy*, 2014

[11] Qinghai Ou, YanZhen, XiangzhenLi, YiyingZhang, Lingkang Zeng “*Application of Internet of Things in Smart Grid Power Transmission*”, in *proc. of Third FTRA International Conference on Mobile, Ubiquitous, and Intelligent Computing* , 2012.

[12] Rajesh Singh Shekhawat, Ruchika Singh Rao, KajalKumari, Vinod Kumar, “*Solar Panel using Inverter with level indicator*”, International Journal of Innovative and Emerging Research in Engineering, 2016.

[13] S. Balaji, Karan Nathani, R. Santhakumar, IoT Technology, Applications and Challenges: A Contemporary Survey, International Journal of IT, Springer, pp. 363–388, 2019.

[14] Soham, Adhyaet "*An IoT based smart solar photovoltaic remote monitoring and control unit.*" in proc. of 2nd IEEE International Conference on Control, Instrumentation, Energy & Communication (CIEC), 2016.