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A modified Smart Controlling and Monitoring Scheme of Three Phase Photovoltaic Inverter rely on LoRa Technology

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Abstract. Photovoltaics is the core of the greatest current system that using solar energy and it is regarded as the basic of sustainable engineering techniques. It is the method of exchanging daylight straightly to electricity power. The LoRa communication technology is a far-range, economic-power, small rate of bit technology. It is sponsored as a basic settling for the Internet of Things (IOT). This technology is applied where equipment is battery-feed with narrow bandwidth was required. In this manuscript, a novel method that depends on the LoRa technology is considered to observes and governs the power generated from a three-phase Photovoltaics inverter scheme that fed to grid directly. This scheme is designed with dual parts. The first one is for evaluating and control invertor part. This part attaches straight through the inverter to recognize the working of the inverter by changing the state of inverter from far spaces. The second part which is uses the liquid crystal display and a smart-phone observing application. The phone program is prepared using MIT App Inventor to observe and govern the entire scheme. The results show that this system is robust against the circumstances around the system and gives accurate results with minimum error when using in urban lands. The benefit of this system is to monitor and control the photovoltaic system located in remote place without need of attend to generating place.

Keywords: photovoltaic, IOT, LoRa communication, 3-phase inverter

1. Introduction

LoRa is a wireless communication technique that uses little amount of power. The chief benefit is that the demodulation was applicable through a noise amount fewer from twenty dB. This technique is normally applicable for the position near to 20Km. this is done by communicate huge amount of nodes with each other [1]. This network has the ability to reduce the interfering between the node. Therefore, the efficiency of this network was enhanced. The LoRa technique uses the better security technique that is called the chirp spread spectrum. This technique is used in the beginning in military equipment. The Specifications of LoRa communication can be defined as: "Modulation uses are FSK, BASK (OOK) and LoRa modulation, the Possible frequencies are: 109MHz, 433MHz, 866MHz, 915MHz, the space of working is about from 15 to 20km, the level of data is 37.5 kbps, Extended battery

lifetime is about 10 years of working". invent of broadcast the LoRa modulation uses FHSS modulation. The hopping process in frequency in case of broadcast and getting information process begins with "channel 0" [2,3]. The header is transferred primary within "channel 0". LoRa aims arrangement sat the place when the equipment as restricted power (that means when powered by battery). In this case the terminal device need to transmits small amount of information at moment. The big range and lower-energy specification of this technique lead to benefit from this technique for "smart sensing technology, health monitoring, smart metering, environment monitoring and industrial applications". This LoRa structure goals for working in prolonged time for the device working with battery in which the power consumes is the important factor. LoRa be able to usually denote to dual separate layers. The first one is the physical layer consuming the "Chirp Spread Spectrum (CSS)". The second one is the "MAC layer protocol (LoRa WAN)" [4,5].

2. The LoRa Physical Layer

LoRa technology employs the "chirp spread spectrum modulation". This technique works with a non-deviating alteration of frequency with in period for encode data. Owing to the linear property of the chirp pulsates, frequency substitute among the receiver and transmitter are same to period offsets. This is simply removed in the decoder. That property gives the indication that this modulation resistant against Doppler effect that is equal to a frequency offset. The phenomena of "frequency offset between the transmitter and the receiver" may be equal to twenty percent of the band-width with-out affect decoding execution. This assists with decreasing the cost of LoRa transmitters, as the precious stones inserted in the transmitters don't should be fabricated to extraordinary precision. LoRa collectors can bolt on to the recurrence tweets got, offering an affectability of the request of 130 dBm. As the LoRa code length is taller than the ordinary blasts of AM confusion created by "Frequency Hopping Spread Spectrum (FHSS)" scheme, mistakes produced by such obstruction are effectively remedied through "Forward Error-correction Codes (FECs)" [6].The ordinary outside of bath selectivity (the most extreme proportion of intensity between an interposer in an adjacent band and the LoRa codes) and co-channel dismissal (the major proportion of intensity between an interposer in a similar channel and the LoRa codes) of LoRa recipients is individually ninety dB and twenty db. This beats conventional modulation scheme, for example, (FSK) modulation, and makes LoRa appropriate to low-energy and extended-zone transportation [7].

The internet of things has a layered construction considered to response the needs of numerous manufacturing, creativities and culture. Figure 1 displays a general layered construction for internet of things that contain of five layers. These five layers are: "Edge Technology layer, Access Gateway layer, Internet layer, Middleware layer and Application layer" [8].
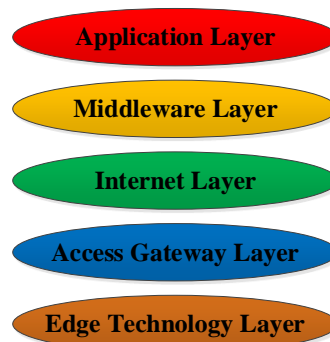
Application Layer

Middleware Layer

Internet Layer

Access Gateway Layer

Edge Technology Layer

Figure 1. Layered construction of the Internet of Things [1].

2.1. Parameters of the Physical Layer

A various factor is accessible for the selectivity of the LoRa modulation. these parameters are "Bandwidth (BW), Spreading Factor (SF) and Code Rate (CR)". LoRa utilizes an unusual meaning of

the spreading factor as the logarithm, in "base 2", which represents the account of chirps for every symbol. Propositions parameters impact the viable bitrate of the modulation, its protection from obstruction noise and its simplicity of decoding. The BW is the ultimate essential factors of the LoRa modulation [9]. A LoRa code is made out of 2*SF chirp that overlay the whole freq. range. It begins with a progression of upward chirp. At the point when the greatest freq. of the period is achieved, the freq. folds over, and the expansion in freq. begins and still from the lower freq. Figure 2 explain a case of a LoRa transport in the freq. variety within timing. The situation of this irregularity in freq. is the thing that encodes the data broadcast. it represents 2*SF chirp in a code. a code is active encode (S*F) bits of data [10].
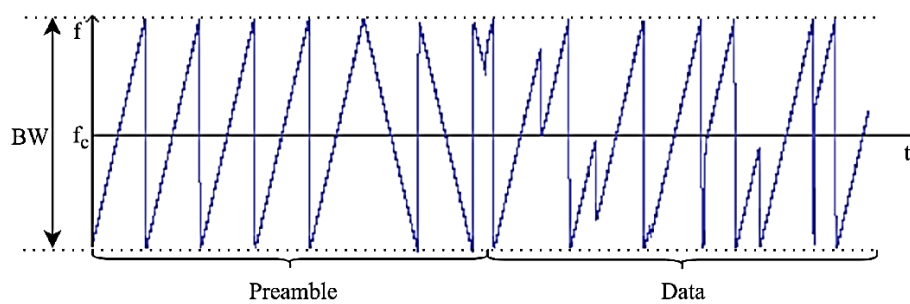

Figure 2. The alteration of freq. through entire period of time for transmitted LoRa signal [3].

In LoRa, the chirp speed relies on the BW that means "one chirp per second per Hertz of bandwidth". It has numerous result on the modulation this means "an increase of one of the spreading factor will divide the frequency span of a chirp by two as 2^{SF} chirps cover the whole bandwidth and multiply the duration of a symbol by two, also". That words are decoded within Equation 1, that relations the period of a symbol (TS) to the BW and the SF.

$$Ts = \frac{2^{SF}}{BW} \qquad (1)$$

Also, the LoRa contains a "forward error correction code FEC". The CR = 4/(4 + n).the factor $n \in \{1,2,3,4\}$. it can be said that Eqn. 2 permits to calculate the beneficial "bit rate (R_b)".

$$R_b = SF \times \frac{BW}{2^{SF}} \times CR \qquad (2)$$

Also, it can be said that these factors are effect "decoder sensitivity". from this words it will conclude that the cause of reducing the receiver sensitivity is the rise of the frequency band. Also can conclude the rising of SF will be rising receiver sensitivity. Also lowering the rate of data will lower the "Packet Error Rate (PER)". Table 1 indicate the relation between and the SF and gives the real values of receiver sensitivity in dBm [11].

Table 1. the values of receiver sensitivity in dBm at different values of BW and SF.

BW	SF =7	SF =8	SF =9	SF=10	SF =11	SF =12
125Khz	-123	-126	-129	-132	-133	-136
250Khz	-120	-123	-125	-128	-130	-133
500Khz	-116	-119	-122	-125	-128	-130

2.2. The Physical Layer Frame Format
The format of the physical frame is quantified and realized in "Semtech's transmitters and receivers". The BW and SF are not altered during the frame. frame of LoRa starts with a preamble. It begins with a series of continuous up "chirps" that shield the entire band of frequency. The latest double chirps encrypt the synchronous data. The synchronous data consist of one-byte amount which using for distinguish between the LoRa nets which used the similar range of frequency. The entire period for

preamble is organized among 10.25 and 65,539.25 codes. then there is new part of frame which is "header". This is optional and can be seen or not depending on the types of frame. In case when head is seen it takes the code of the rate with amounts of 4/8. Also specifies the amount for payload, the rate of code utilized within finale broadcast. The frame besides contains a CRC to permit receiver to reject packets that contains in acceptable header. The dimension of the payload is kept spending single byte, restrictive dimension for payload is 255 bytes [12]. The frame arrangement for LoRa communication is shown in figure 3. Table 2. Instrument/analytical method used for water quality parameters.
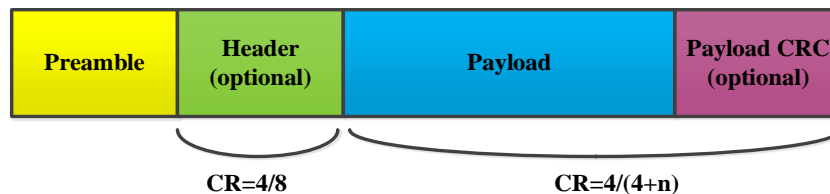

Figure 3. frame Construction of a LoRa communication [9].

The previous equations derivative via "Semtech's datasheets". This provides the amount of codes needed to broadcast a payload ns. This amount would have summed with the amount of codes for the preamble. This is done to computes the entire dimension of packet in codes. In Equation 4 the *PL* represents the payload dimension in byte. the *CRC* was 16 in case of permitted while take zero amount in other cases. The amount of *H* is twenty in case of header was allowed while take zero in other case. The *DE* is 2 in case of small rate of data optimize is permitted while take the null value in other cases. Equation 4 explain the lower dimension of packet is 8 symbol.

$$n_s = 8 + max\left(\left\lceil \frac{8PL - 4SF + 8 + CRC + H}{4 \times (SF - DE)} \right\rceil \times \frac{4}{CR}\right) \qquad (3)$$

It can be seen from figure 4 when take the message format for LoRa communication in details and in deep sight and this message contains: "DevAddr is the short address of the device. FPort is a multiplexing port field. The value zero means that the payload contains only MAC commands. When this is the case, the FOptsLen field must be zero. FCnt is a frame counter. MIC is a cryptographic message integrity code, computed over the fields MHDR, FHDR, FPort and the encrypted FRMPayload. MType is the message type, indicating among other things whether it is an uplink or a downlink message and whether or not it is a confirmed message. Acknowledgments are requested for confirmed messages. ADR and ADRAckReq control the data rate adaptation mechanism by the network server. ACK acknowledges the last received frame. FPending indicates that the network server has additional data to send and that the end-device should send another frame as soon as possible so that it opens receive windows. FOptsLen is the length of the FOpts field in bytes. FOpts is used to piggyback MAC commands on a data message. CID is theMAC command identifier, and Args are the optional arguments of the command. FRMPayload is the payload, which is encrypted using AES with a key length of 128 bits. The minimal size of the MAC header is 13 bytes; its maximal size is 28 bytes". when packets are transmit starting via a device to network or from network to device, there is nope target address on up packets [13]. Also, there is nope source addresses on down packets.

3. The Photovoltaics structure

A photovoltaic structure usages solar boards for catching sunlight's photons. this solar boards a piece contains numerous solar cubby manufacture from sheets of altered material. The no reflective covering on upper benefits the cell catches maximum amount of light. As soon as the photons are taken by the solar cubby, it starts freeing the external electrons of atoms inside the semi-conductor. The both side of the conductors generate a path to electrons. This lead to current is generated. This current is transfer through cables that release the D.C. energy. This cables connect to an inverter. After that this inverter transform the DC energy to AC energy. A photovoltaic structure (PV) is prepared to provide service able solar energy through photovoltaics. The system contains a preparation of numerous parts. This parts contains "solar panels to absorb and convert sunlight into electricity, a solar inverter to change

the electric current from DC to AC, as well as mounting, cabling, and other electrical accessories to set up a working system" [14]. In order to improves the performance of the system the solar tracking system may be used.
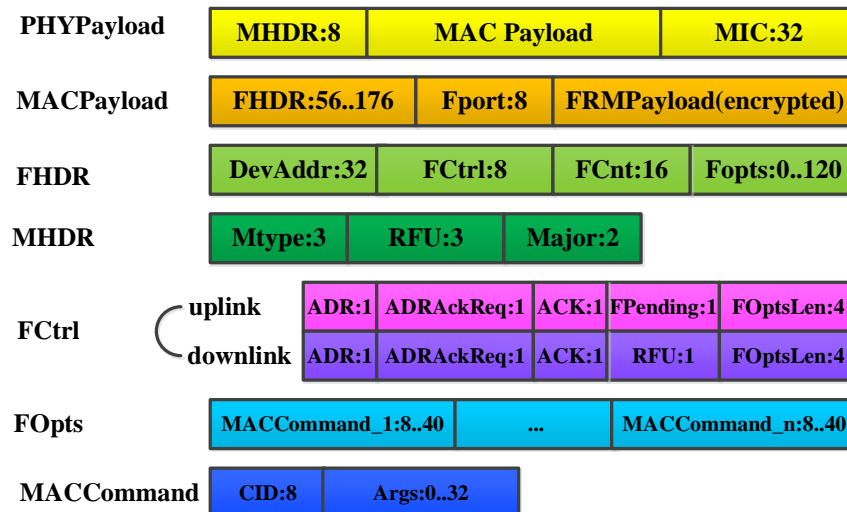

Figure 4. The frame format in details for LoRa communication [11].

4. System Description

The smart monitoring and control system (SMCS) of the three-phase photoelectric is discussed in detailed within this part from the side of hardware model and software model and the main blocks of the system. The hardware section within planned structures separated to dual portions. These two parts are the sending and receiving parts. The central portion of the sending part and receiving part is the "LoRa Kit 32". To do this mission double software programming are utilized to complete the structure. The first one is to encoding microcontroller while another one for designing the phone observing and govern program. The suggested scheme delivers dual kinds of "wireless communication protocols". First of all, LoRa units is rapid spot-to-spot net. to transmit the evaluating information from PV side to the chief position or manager person. The second one, as soon as the information is taken via the chief position, it will transmit directly end operator through Bluetooth technique to monitor and govern through phone program.

The hardware combination of the smart monitoring and control system is separated to dual components. the transmitter portion to measure and control the system. the receiver portion to monitor and control the scheme. The chief part within sender and receiver of smart monitoring and control system was the "LoRa Kit 32". The LoRa Kit 32 was the novel advance boarding with lower charge active, lower rates of bits, extended domain lower energy consuming while the core chip employ "Lexin ESP32 and Tensilica LX6 dual-core processor". Figure 5 displays the LoRa technology and the component that is used in the new system. The system can be divided into two parts which are:

1. Measure and Controlling scheme

This is known as the Sender Portion of the system. It can be separated to three portions: "measuring, control and communication".

a) the Measure part: this part is shown in Figure 6(a) contains of a three-phase opto-coupler separation part connecting to the O/P of the PV system to check the O/P volts. This system is for testing if A.C. 250V. be present once there is network volts of extra from 200V. The O/P of the opto-coupler system is "Small" since the opto-coupler is linked to the grounds. else, the O/P was "Great" since it was never conducted to ground.

b) the part for system Control: the control system which is shown in Figure 6(b). this circuit is within this scheme to change the state the SMCS between ON and OFF via separating the DC-connection for the SMCS.

c) the system of Communication: the "LoRa communication board" can be shown in Figure 6(c). this circuit is utilized for sending the situation for SMCS to central location and receiving the information for changing the state of SMCS between ON and OFF.

2. The Monitoring and Controlling system
This circuit is representing the Receiver Part. the central action for that part is communicating in the midst the sending system with the ending user. This system receiving information from the sending system via LoRa technology. After that sending the information to the end user through Bluetooth to observe through a smartphone program. The signal that will be monitored which represented the three phase voltages for the photovoltaic system can be shown in figure 7.
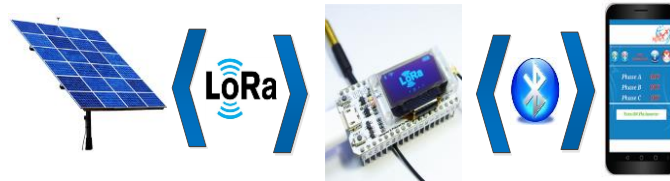

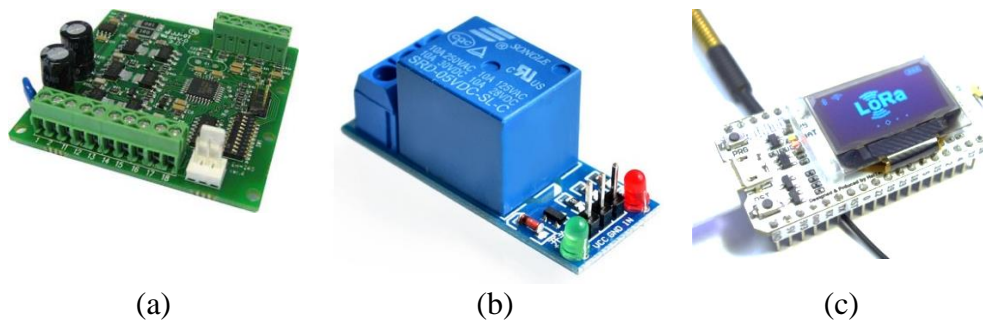**Figure 5.** the component of the SMCS.

(a)   (b)   (c)

Figure 6. Chief real parts of SMCS:(a) the sensor of three phase voltage. (b) the part of control system. (c) the hardware of LoRa

5. The Software of SMCS
Two types of program are used in this work, the first one is the ESP32 microcontroller (for transmitting and receiving data). This measures and controls the circuit (transmitter) to read the data from the voltage sensors circuit, then sends the results by the LoRa communication technique to the base station (receiver), then the monitoring and control circuit (receiver), and communicates between the transmitter circuit and the end user by using the LoRa communication technique and Bluetooth. The second program is for monitoring the received data from the transmitter microcontroller. The monitoring system or monitoring software of the SMCS is a new application designed to be installed on an android smartphone or a tablet and is a monitoring and control application. the application program was designed by the open source MIT App Inventor 2.
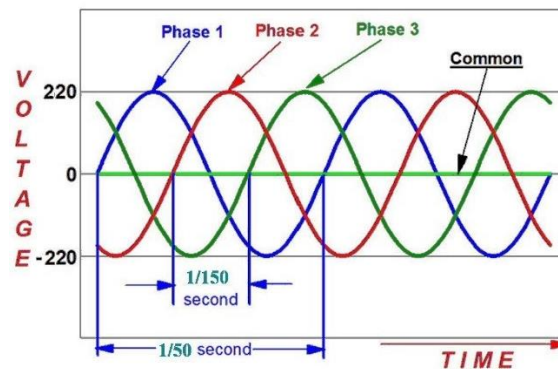
Figure 7. the three phase voltage of the photovoltaic

6. Results and Discussion

Figure 8 shows the entire new scheme of clever observing and control of the "three-phase photovoltaic inverter". The scheme contains two parts, which are: calculating and control scheme which is presented in Figure 8(a) while the checking and control scheme was displayed in Figure 8(b). The system was tested within workroom to verify its ability.

Figure 9 shows the flow chart of the entire system of control in addition to monitoring system of photovoltaic. This flowchart was consisting of three parts which are: the first one which is shown in figure 9(a). this figure used to explain the measure and control device which is used to examine the state of the 3-phase O/P for the invertor and transmit the information to the core station via LoRa system. also it is used as the method in which it can determine the ability to turn ON/OFF the invertor depends on the information which is coming for the core or main part. The second part of the flowchart which is demonstrated in Figure 9(b) is represent the control and monitor part of the receiving side. In this part the system was taken the information from the evaluating and controlling scheme. After that the taken data was shown in the liquid crystal display. The third or final part of the flowchart which is explained in figure 9(c) is represent the flowchart of the application program which is transferred to the user using the Bluetooth technology.

The application or program for the new technique which is named SMCS was shown in figure 10. The figure 10(a) represent the system when it is not connected to the smartphone. in that case it is shown that all the values of the three phase voltage refer to zero value and the status of Bluetooth is disconnected. The second part of the application which is shown in figure 10(b) represents the case when the application is connected to the system. In this case it is shown the values of the three phase voltages was changed to normal value which is about 220 volts and the system received the information from the measuring side.
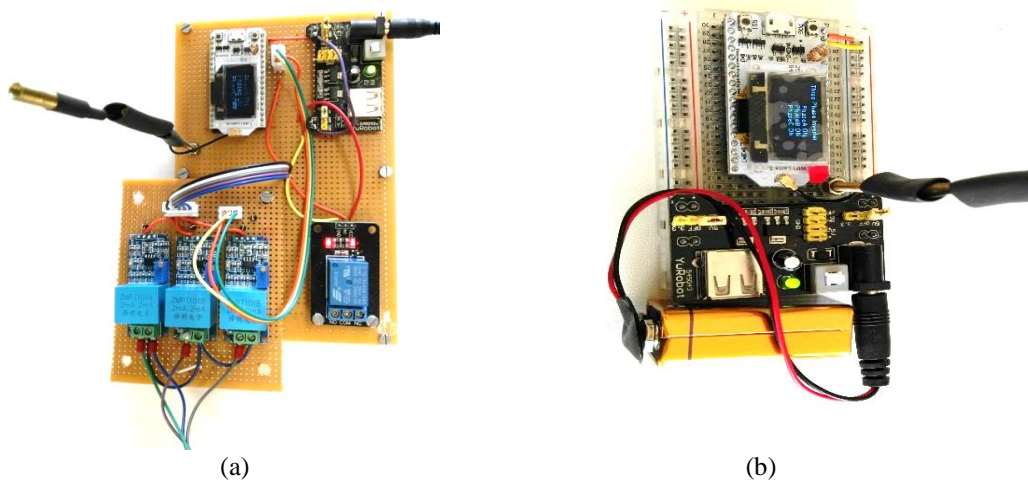

(a)   (b)

Figure 8. The real structure: (a) the operation circuit (b) the control part.
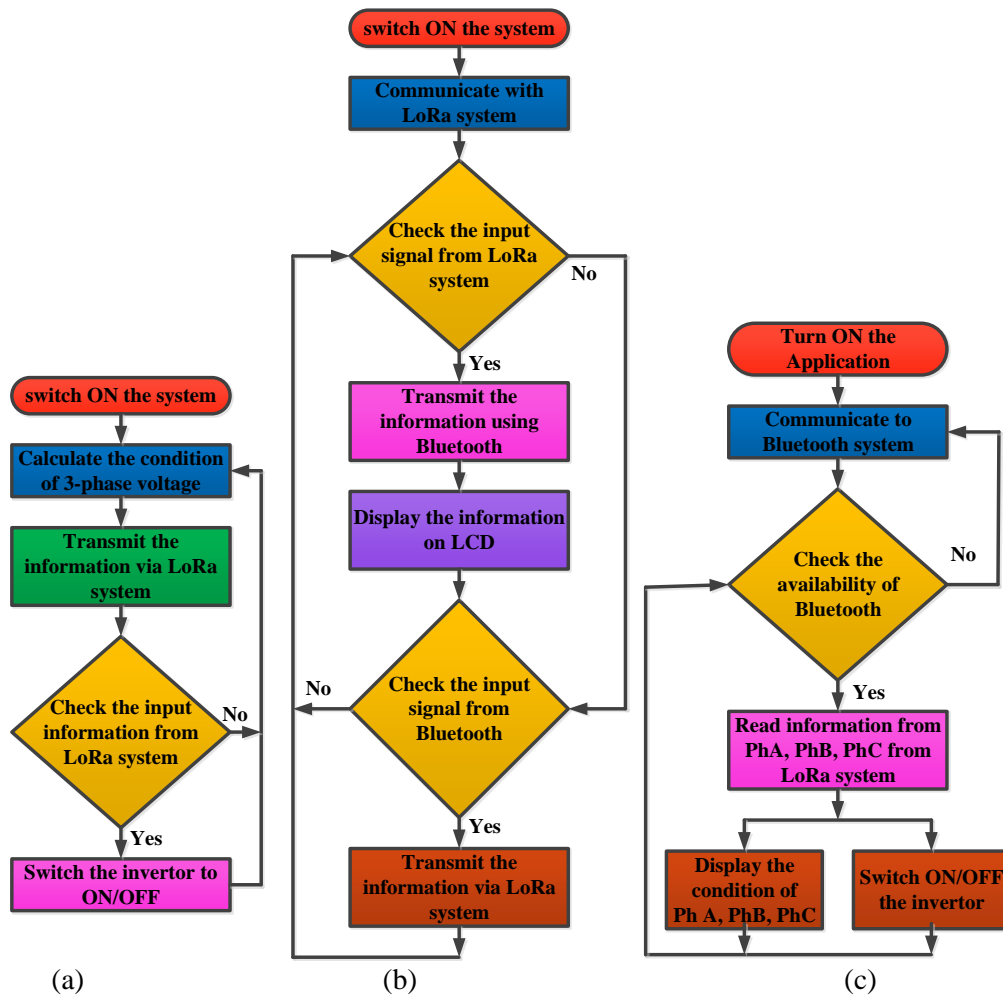
Figure 9. the complete flowchart of the new system: (a) the system of transmitter flowchart. (b) the system of receiver flow chart. (c) the flowchart of smartphone application.
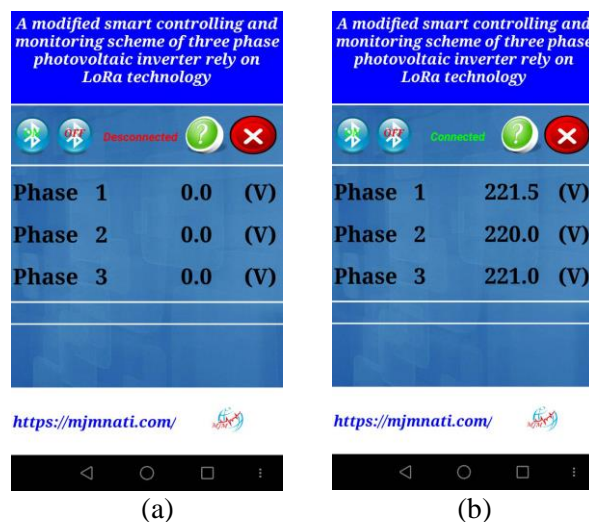

Figure 10. the software for the new system (SMCS)

7. Conclusions

LoRa is the technique that represents the meaning of internet of things or IOT. it is the far distance lower dissipated energy techniques that is used for communication. This paper demonstrates the entire analysis of the LoRa specification and information about the new system that is depends on this technique. The results explained that LoRa ability which uses the "chirp spread spectrum modulation" and great receiver sensitivity. This technique gives the high immunity against the interference. experiments indicate that LoRa was offers suitable system coverage till three kilometers in urban zone. Over all this words it can be said that in this work, we have designed a smart monitoring and control system for the management of renewable energy harvested by a three-phase photovoltaic inverter tied to grid. The LoRa technology has been used as a communication network between the Photovoltaic system and the main solar power station. A hardware and LoRa network have been successfully designed and implemented with a real three-phase inverter in the laboratory. In addition to the use of LoRa technology, Bluetooth was used to read the data by smartphones inside the solar power station. A new special smartphone application was designed for monitoring and control for this purpose.

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