Roshan Ghosh / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 2, Issue 3, May-Jun 2012, pp.2903-2911

DTMF Based Controller for Efficiency Improvement of a PV Cell & Relay Operation Control

Roshan Ghosh*
*(Department of Electrical Engineering, TRIPURA University, Tripura, India)

ABSTRACT
The human mind always needs information of interest to control systems of his/her choice. In the age of highly advanced electronic systems many methods of remotely control systems have been developed, these methods have the problems such as the need for special devices and software to control the system. This paper suggests a method for control using the DTMF tone generated when the user pushes mobile phone keypad buttons or when connected to a remote mobile system. This DTMF based controller is used to control the operation of multiple relays & also for the purpose of efficiency improvement of a PV cell by regulating the open circuit voltage of the cell. The proposed work has been done experimentally in Labview 7.1 software.

Keywords - **DTMF, MPPT, PV cell, Relay, Voltage regulator**

1. INTRODUCTION
The remote control technologies have been used in the fields like factory automation, space exploration, in places where human access is difficult as this has been achieved in the domestic systems partially [1,2].Existing systems are expensive to implement as different means of communications are used where instant access is a challenge [3,4]. Existing systems also lack the security in a real world application that would require while implementing the system in a real world application [5]. So a system is required to be designed such that can offer way out for both instant access & security.

The proposed system attempts to provide a cost effective solution to the problems found in controlling devices from off-site. The method of remote control is modified in this system focusing on faster action and diversity of applications. As the mobile phone enables us to connect with the outside devices via mobile communication network regardless of time and space, the mobile phone is a suitable device to send control signals to remote systems. Method proposed here uses the DTMF (Duel Tone Multi Frequency) [4, 6] when keypad button of mobile phone is pressed by the user. The mobile phone user controls the system by sending DTMF tone to access point. Mobile communication network is larger than LANs, thus user can take advantage of mobile phones to control the system.

The suggested system controls the operation of multiple relays and also generate voltage regulation signals to improve the efficiency of PV cells. As many of the solar plans are established in the remote areas so using this DTMF based controller user can control the protective relays and improves the efficiency from remote control room.

2. DTMF BASICS
Duel Tone Multi Frequency (DTMF) tone is used to identify which key is pressed in the mobile keypad. Mobile keypad is used as password entry device. Pressing any key generate unique tone which consists of two different frequencies one each of higher and lower frequency range. The resultant tone is convolution of two frequencies [1,2].The frequencies and their corresponding digits are shown in Fig 2.1.

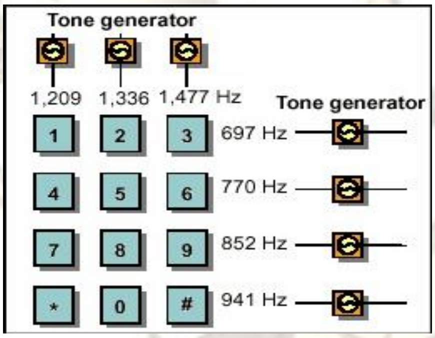


Figure 2.1.Phone keypad for DTMF tone generation

Each of these tones is composed of two pure sine waves of the low and high frequencies superimposed on each other. These two frequencies explicitly represent one of the digits on the telephone keypad [7]. Thus generated signal can be expressed mathematically as follows:

$$f(t) = AH \sin(2\pi fH\, t) + AL \sin(2\pi fL\, t)$$

Where AH, AL are the amplitudes & fH, fL are the frequencies of high & low frequency range. Properties of DTMF tone frequencies are:

- No frequency is an integer multiple of another
- The difference between any two frequencies does not equal any of the frequencies
- The sum of any two frequencies does not equal any of the frequencies

There are three options for communication to implement in communication system:

- Wireless Internet Platform (WIP)
- Short Message Service (SMS)

- DTMF Signal

WIP requires cost of network data usage for communication but DTMF does not [8]. As SMS requires external server to communicate, it causes delay [9]. But DTMF signal system will allow real time control of the devices. Using of DTMF makes system simpler to implement and independent of mobile operator. Among the three options DTMF signal is most convenient and the cheapest for the above mentioned reasons.

3. PHOTOVOLTAIC SYSTEMS & RELAYS

3.1 Solar resource

Knowledge of the sun is very important in the optimization of photovoltaic systems [10]. Solar energy is the most abundant renewable resource. The electromagnetic waves emitted by the sun are referred to as solar radiation. The amount of sunlight received by any surface on earth will depend on several factors including; geographical location, time of the day, season, local landscape and local weather. The light's angle of incidence on a given surface will depend on the orientation since the Earth's surface is round and the intensity will depend on the distance that the light has to travel to reach the respective surface. The radiation received by a surface will have two components one which is direct and will depend on the distance the rays travel (air mass).

Figure 3.1 Types of radiation from the sun

The other component is called di use radiation and is illustrated in Fig 3.1. The range of wavelengths of light that reach the earth varies for 300 nm to 400 nm approximately [11]. This is significantly different from the spectrum outside the atmosphere, which closely resembles 'black body' radiation, since the atmosphere selectively absorbs certain wavelengths.

3.2 PV cell

PVs generate electric power when illuminated by sunlight or artificial light. To illustrate the operation of a PV cell the p-n homo junction cell is used. PV cells contain a junction between two different materials across which there is a built in electric field. The absorption of photons of energy greater than the band gap energy of the semiconductor promotes electrons from the valence band to the conduction band, creating hole-electron pairs throughout the illuminated part of the semiconductor [12].These electron and hole pairs will flow in opposite directions across the junction thereby creating DC power.

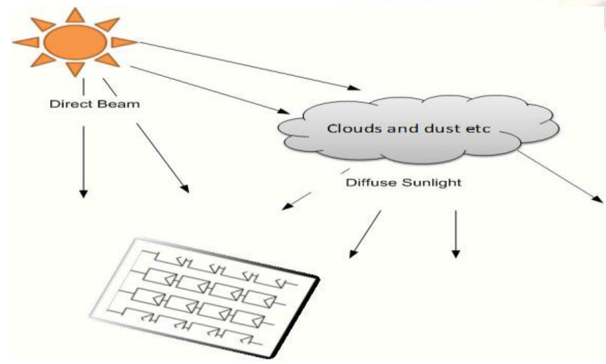


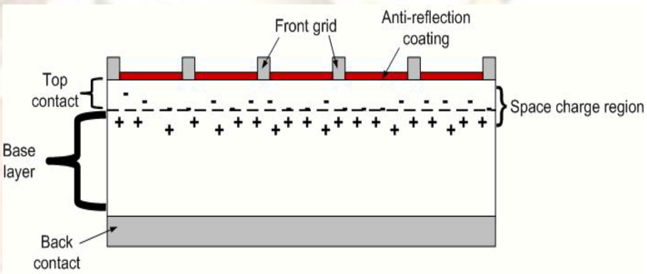
Figure 3.2 Structure of a PV cell

The cross-section of a pv cell is shown in Fig. 3.2. The most common material used in pv cell manufacture is mono-crystalline or poly-crystalline silicon. Each cell is typically made of square or rectangular wafers of dimensions measuring about 10cm × 10cm × 0.3mm [13]. In the dark the PV cell's behavior is similar to that of a diode and the well known Shockley-Read equation can be used to model its behavior

$$i = Is\ [\, e^{\frac{qv}{\beta kT}} - 1\,]$$

3.3 PV cell modeling

Photovoltaic (PV) systems have been used for many decades. Today, with the focus on greener sources of power, PV has become an important source of power for a wide range of applications. Improvements in converting light energy into electrical energy as well as the cost reductions have helped create this growth. Even with higher efficiency and lower cost, the goal remains to maximize the power from the PV system under various lighting conditions [14].



The power delivered by a PV system of one or more photovoltaic cells is dependent on the irradiance, temperature, and the current drawn from the cells. Maximum Power Point Tracking (MPPT) is used to obtain the maximum power from these systems. Such applications as putting power on the grid, charging batteries, or powering an electric motor benefit from MPPT. In these applications, the load can demand more power than the PV system can deliver. In this case, a power conversion system is used to maximize the power from the PV system.

There are many different approaches to maximizing the power from a PV system, these ranges from using simple voltage relationships to more complex multiple sample based analysis. Depending on the end application and the dynamics of the irradiance, the power conversion engineer needs to evaluate the various options.

Fig 3.3 shows a simple model of a PV cell. Here Rs is the series resistance associated with connecting to the active portion of a cell or module consisting of a series of equivalent cells. Rp is parallel leakage resistance and is typically large, > 100k in most modern PV cells. This component can be neglected in many applications except for low light conditions. Current through the diode is represented by

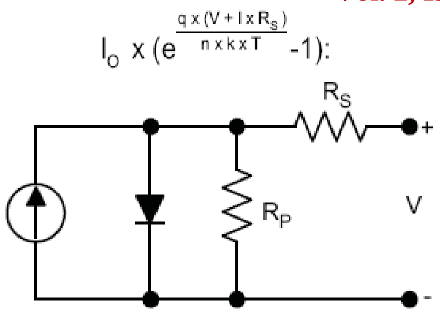


Figure3.3. Simple PV Model

Using equation 3.1 and I-V measurements can be done of a pv cell.

Simple PV output current:

$$I = I_{ph} - I_o \times (e^{\frac{q \times (V + I \times R_S)}{n \times k \times T}} - 1) - \frac{V + I \times R_S}{R_P} \qquad (3.1)$$

Where:

Io = Diode saturation current

T = Temperature (°K)

n = Ideality factor (from 1 to 2)

q = Electron charge (1.6×10^{-19} C)

k = Boltzmann constant (1.38×10^{-23} J/K)

Iph = Photocurrent depends on the that amount of solar radiation it receives

Photovoltaic systems (PV) are a device consists of several solar cells; each cell is associated with each other either in series or parallel to form a series of PV that is generally referred to as PV modules Energy conversion efficiency of solar cells depends on the maximum operating point (MPP) of PV systems [15]. Characteristics of photovoltaic system is highly non linier which influenced by external factor. Solar irradiation, ambient temperature and wind speed are the main environment factor affecting PV system. While the short circuit current (Isc), open circuit voltage (Voc), maximal voltage (Vmax) and MPP current (Imax) are the main parameters that determine operating points of pv cell.

3.4 Relay

A relay is an electrically operated switch. Many relays use an electromagnet to operate a switching mechanism mechanically, but other operating principles are also used. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits, repeating the signal coming in from one circuit and re-transmitting it to another [16]. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

A type of relay that can handle the high power required to directly control an electric motor or other loads is called a contactor. Solid-state relays control power circuits with no moving parts, instead using a semiconductor device to perform switching. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults; in modern electric power systems these functions are performed by digital instruments still called "protective relays"[16].

This paper suggests a method to operate relay as switch by pressing keys of DTMF keypad. 12 different relays has been operated using 12 different keys of DTMF keypad, so multiple relays can be operated by DTMF controller while connected to remote DTMF system.

4. BLOCK DIAGRAM

The entire system block diagram is shown in Fig 4.1.DTMF keypad with 12 keys is designed as 4 × 3 matrix. Two different frequency values are chosen against every pressed key from two different lists of array containing frequency values. Then individual tone properties are measured in the tone measurement section by spectral measurement, FFT peak value & tone amplitude value measurement. In the relay operation section of the block diagram by comparing different measured tone amplitude ranges 12 different relays acting as switch has been operated by pressing 12 different keys of DTMF keypad. Then using the same DTMF keypad

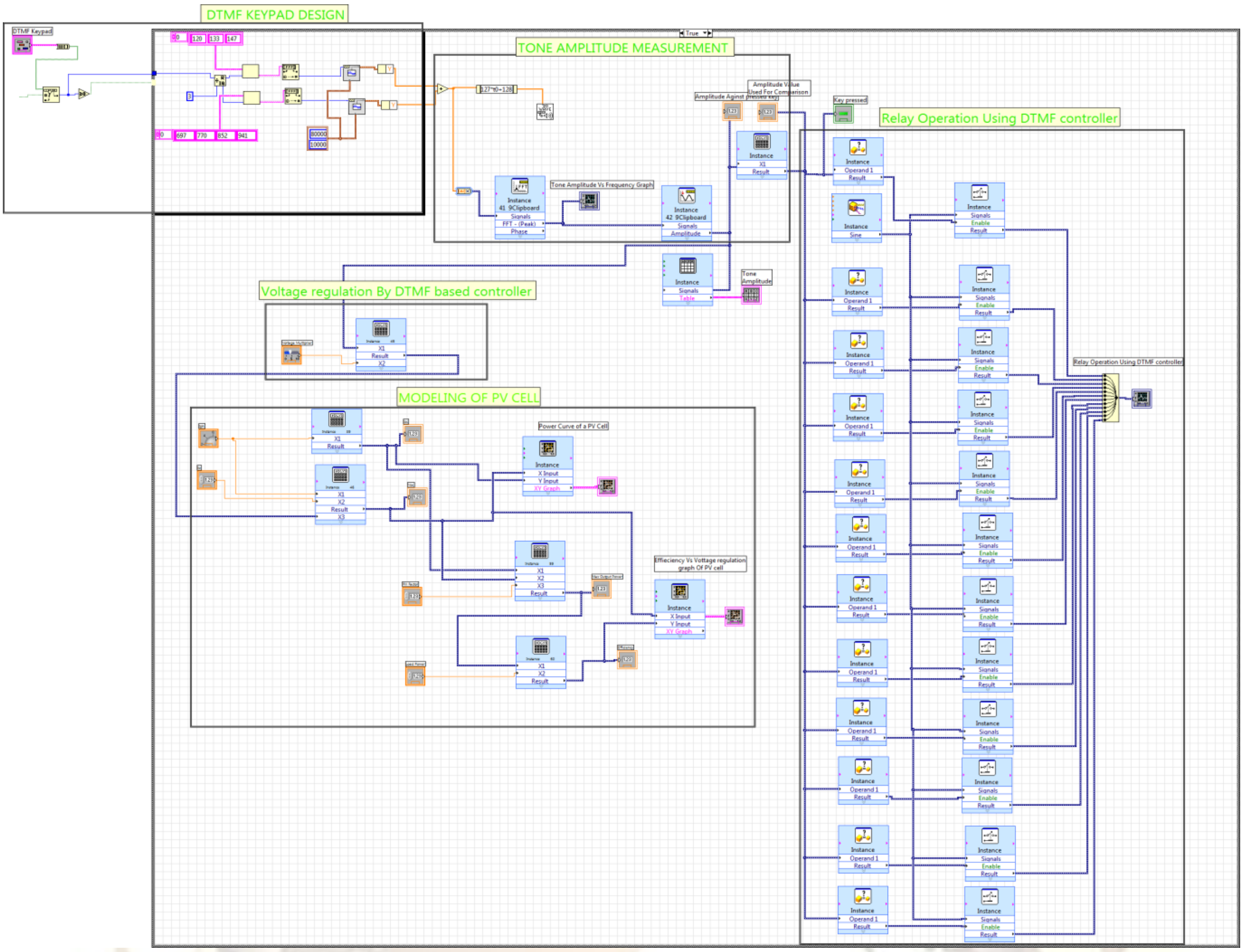


Figure 4.1 Block diagram of DTMF based controller for multiple relay control & efficiency improvement of a pv cell

open circuit voltage (Voc) of pv cell regulated in such a way that the efficiency of that pv cell improves. When a key is pressed from the DTMF keypad it comes to 'Cluster to array' conversion block. The value entered by the keypad is converted to array and entered to a 1-D Array & then to the case structure. The quotient & remainder function values are set with 3 as divisor. Since the numbers on the keypad are arranged in three columns and four rows, the remainder of this operation becomes the column index, and the quotient becomes the row index. Based on the column and row indices a high and a low tone value are chosen using two 1-D array constants. The low and high tone values are wired to a sine waveform VI to generate a waveform based on the chosen frequencies. For getting the components Y function is connected with the generated tone to know t0 is the trigger time of the waveform, dt is the time interval between data points in the waveform. These values are required while connecting the DTMF keypad to system sound driver by [120*t0+128] this expression. Spectral & tone measurements are done in tone measurement section. The PV cell has been modeled considering the equation 3.1 & considering the following equations:

Voc = [(nkT÷q) × ln{(Iph÷Io)+1}]; (4.1)

Fill Factor = [(Maximum Power) ÷(Voc ×Isc)]; (4.2)

Efficiency = [(Maximum power available) ÷ (Load power demand)]; (4.3)

At short circuit the Short circuit Current Isc is almost equal to Iph. During the short circuit only a very small diode current is deducted from the Iph which can be almost neglected. For this Experimental simulation based work taken temp as T=25 ºK, n=1. Voltage multiplier which ranges from 0 to 1000mv to adjust the Voc in such a way that the Overall system efficiency Improves. Here following parameters has been taken from user input Io, Iph, Fill Factor, Load power & the voltage Multiplier that has been used for voltage regulation. Based on these parameters Open Circuit Voltage (Voc) & Short Circuit Current (Isc) has been calculated using the Formulas mentioned in the equations 4.1, 4.2, 4.3 & equation 3.1.

5. SIMULATION RESULTS

5.1 Relay operation control

Table 5.1 shows the tone amplitudes that has been generated by pressing 12 different keys of the DTMF keypad & also the tone amplitude comparison range used for 12 relay operation control.

Fig 5.1 shows the front panel diagram of relay 1 in operation after pressing key 1 from the keypad & in this case tone amplitude is 0.000276 and amplitude comparison range (2.75 - 2.77) is used to detect which key is pressed .Tone amplitude vs. frequency graph is also shown for the generated tone by pressing keys. Similarly Fig 5.2 & Fig 5.3 shows the operation of relay 2 and relay 3 which have been controlled by the duel tones having their individual tone properties. In this way operation of multiple relays can be controlled by pressing different keys from DTMF keypad.

Table 5.1 DTMF tone measured amplitude used for relay operation control

Pressed key	Amplitude of DTMF Tone	Amplitude Comparison range	Operating Relay
1	0.000276	2.75 - 2.77	Relay 1
2	0.000312	3.11 - 3.13	Relay 2
3	0.000342	3.41 - 3.43	Relay 3
4	0.000284	2.83 - 2.85	Relay 4
5	0.000320	3.19 - 3.21	Relay 5
6	0.000349	3.48 - 3.50	Relay 6
7	0.000297	2.96 - 2.98	Relay 7
8	0.000333	3.32 - 3.34	Relay 8
9	0.000362	3.61 - 3.63	Relay 9
*	0.000309	3.08 - 3.10	Relay10
0	0.000345	3.44 – 3.46	Relay11
#	0.000373	3.72 – 3.74	Relay12

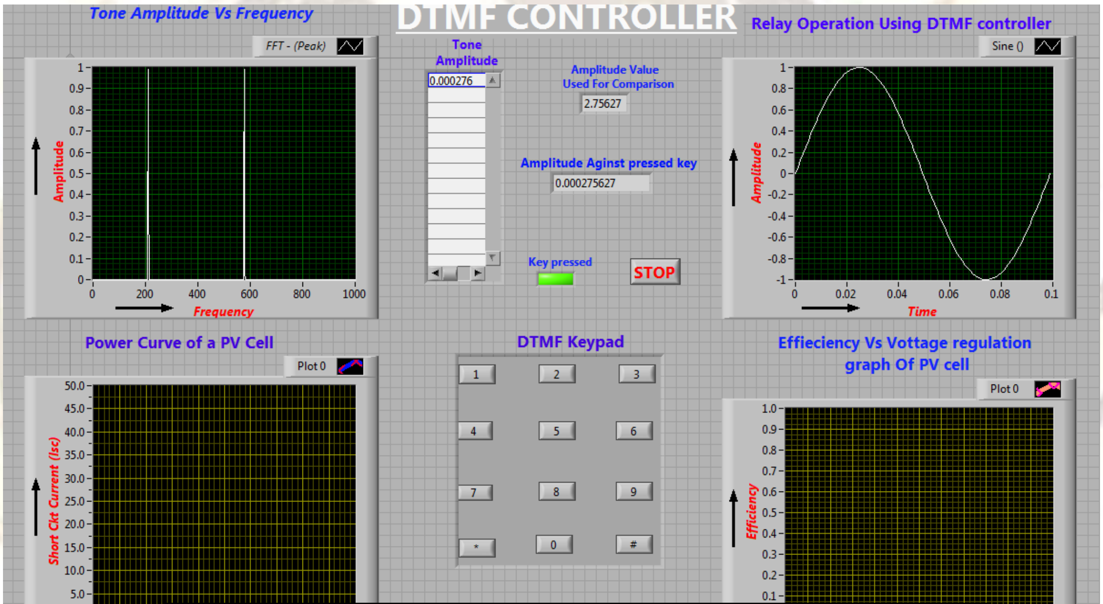
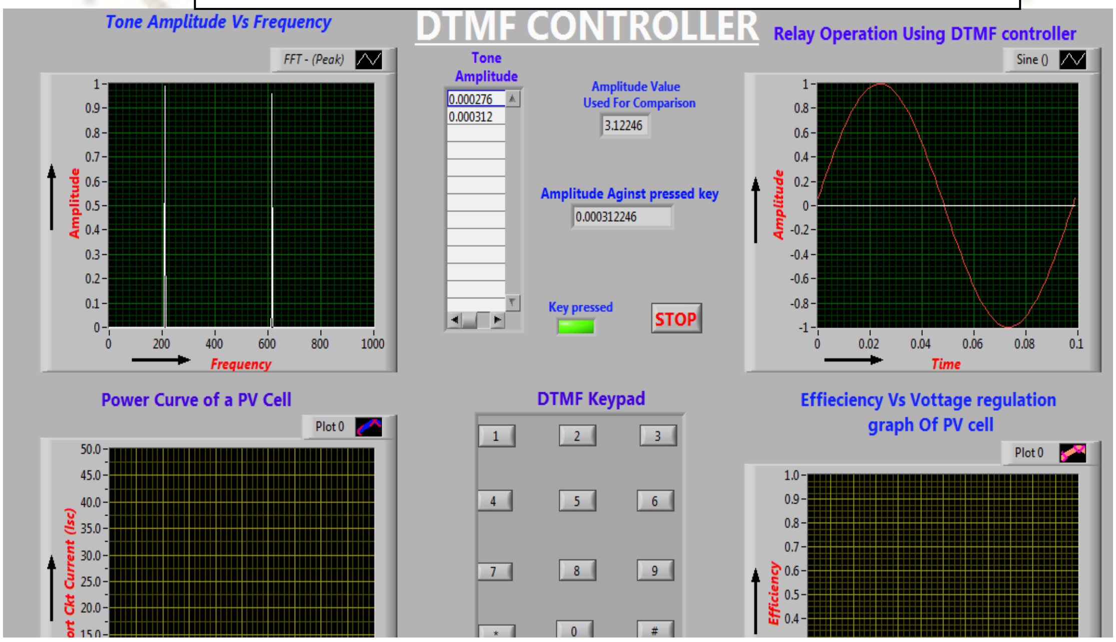


Figure 5.1 Relay 1 in operation by pressing key 1 from DTMF keypad



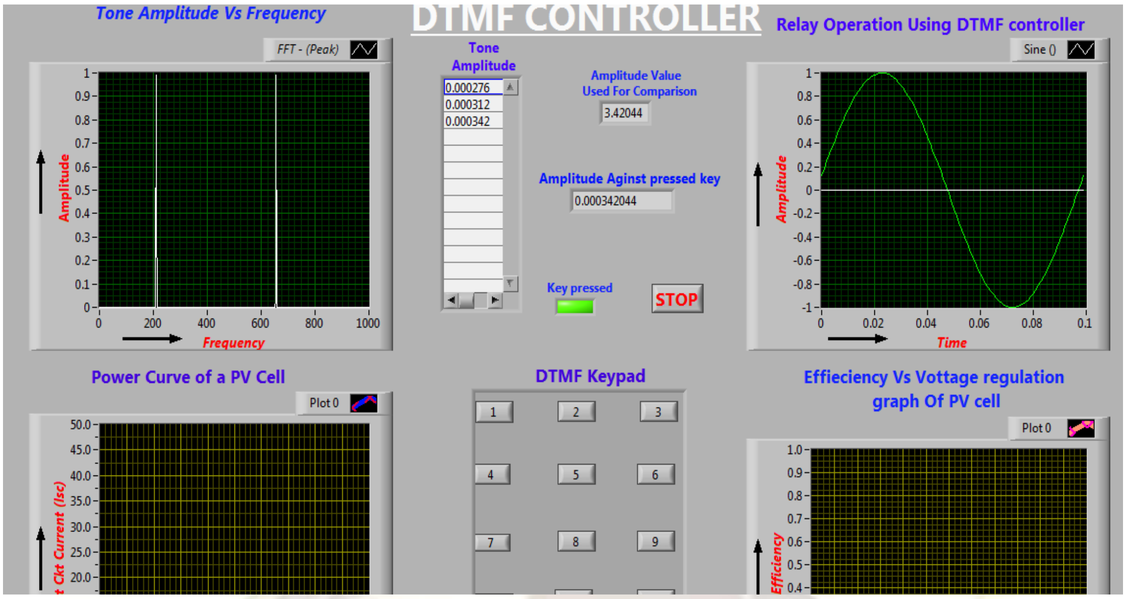


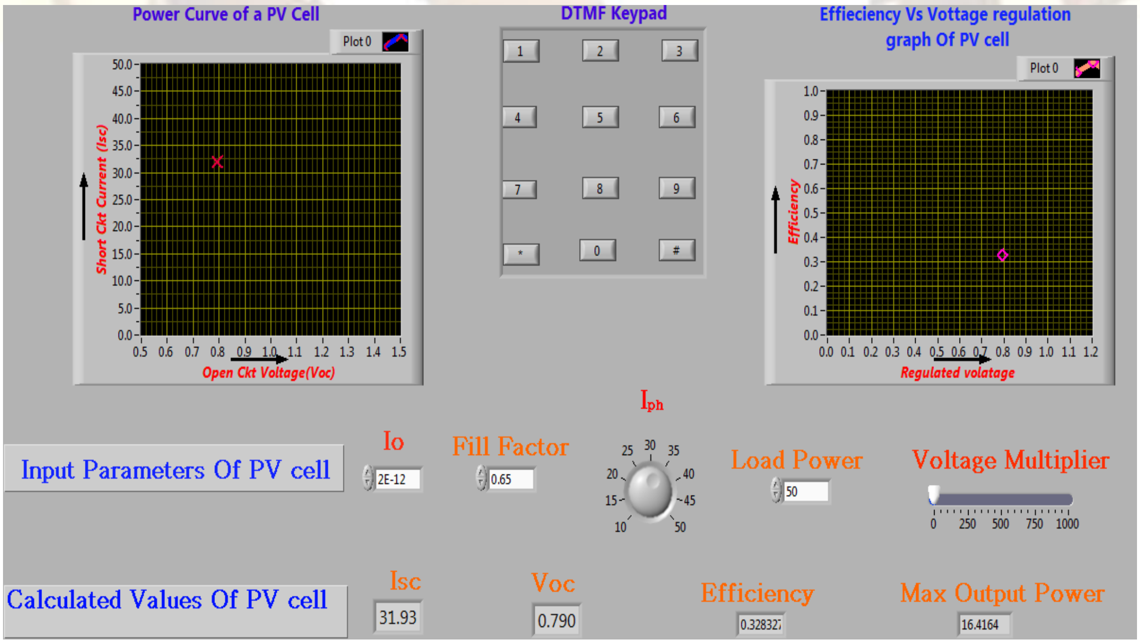
Figure 5.3 Relay 3 in operation by pressing key 3 from DTMF keypad

5.2 Efficiency improvement of a pv cell

Case I

$Io = 0.2 \times (10)^{-12}$ mA, Iph = 30 mA,
Fill Factor =.65
Load Power= 50 watts
Voltage multiplier=0 mv
Temperature considered as constant (25 °K) & also considering n=1 following results are computed from the front panel as shown in the Fig 5.4

Voc= 0.790963 mV
Isc= 31.9306 mA
Maximum Output power= 16.4164 watts
Efficiency= 0.328327
(Voc × Isc) point is shown in power curve of pv cell. Efficiency point is shown when with respect to regulated voltage in the efficiency vs. voltage regulation graph.



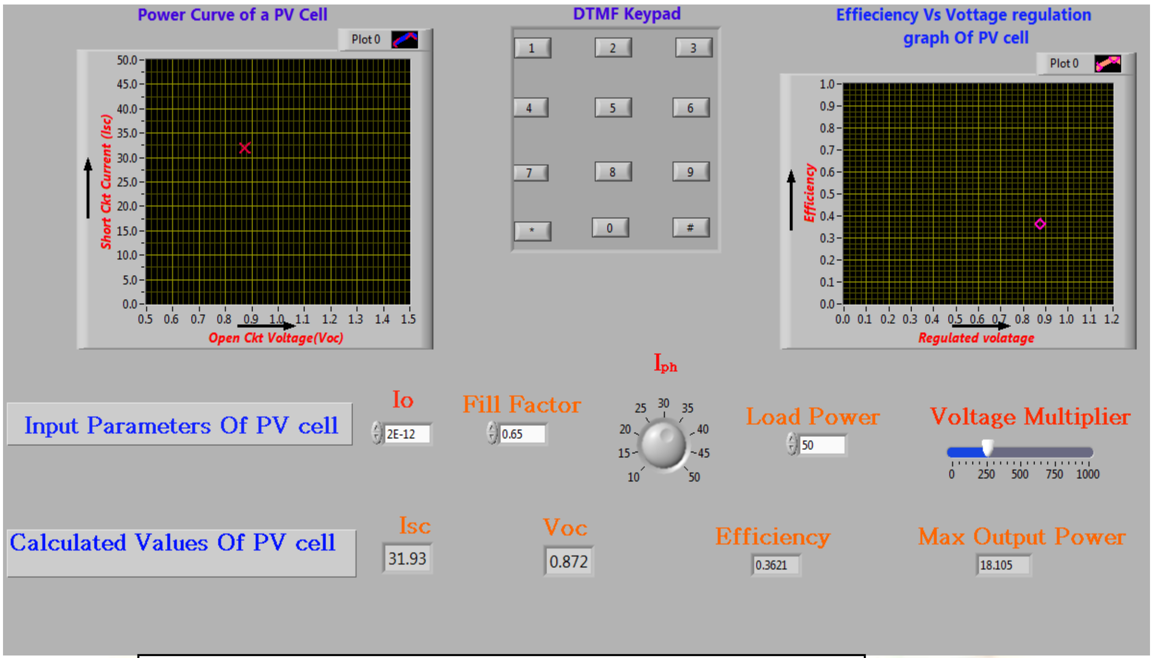


Figure 5.5 Efficiency improvement of pv cell by pressing key 1

To improve the efficiency Voltage multiplier value is set to 250 mV which will increase the open circuit voltage (Voc) of pv cell as shown in the Fig 5.5. Tone amplitudes is multiplied with voltage multiplier and then added to Voc to increase the open circuit voltage while pressing the every key from the DTMF keypad and thus increasing the efficiency of the pv cell. Fig 5.5 shows efficiency increases from 0.32 to 0.35 while pressing the key 1 from keypad. Further improvement of efficiency is possible by pressing key2 and varying the Voc in different range as kay2 has different tone amplitude. Fig 5.6 shows efficiency improves from 0.35 to 0.36 while pressing key 2.In this way by pressing different keys from keypad & selecting voltage multiplier value it is possible to increase the efficiency of a pv cell.

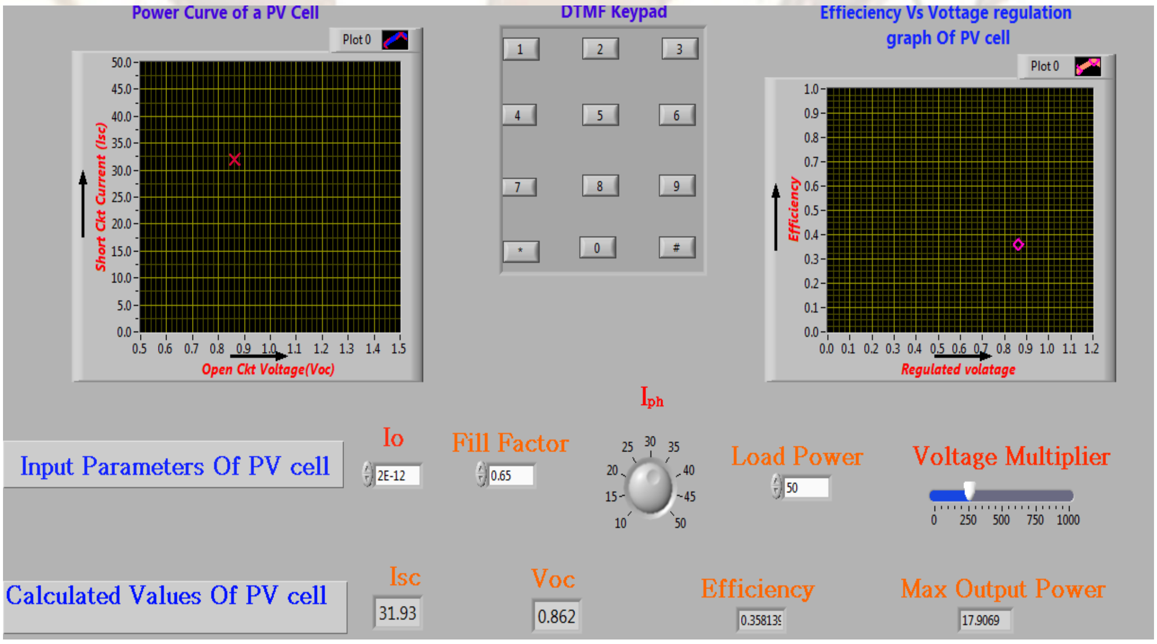


Figure 5.6 Further efficiency improvement of pv cell by pressing key 2

If there is cloudy weather outside or less photovoltaic rays are incident on the PV plate then as the photocurrent Iph is almost equal to Isc and then operating point of pv cell changes. It operates lesser that maximum power point (MPP) which means the efficiency goes down.

In this case it is assumed that the solar radiation goes down such a way that the Iph value which was 30 mA in previous cases now comes down to 15 mA. Fig 5.7 shows that due to the lesser value of Iph the efficiency goes down to 0.17 while other input parameters remains the same.

Now the efficiency is very low (0.17) so now voltage multiplier value is set to 750 mV to improve the efficiency. Fig 5.8 shows efficiency improved up to 0.20 by pressing key 1. Further improvement of efficiency is also possible by pressing different keys & varying open circuit voltage in different ranges.

6. CONCLUSION

In this paper it is shown that relay operation can be controlled by this DTMF signals sent from DTMF based

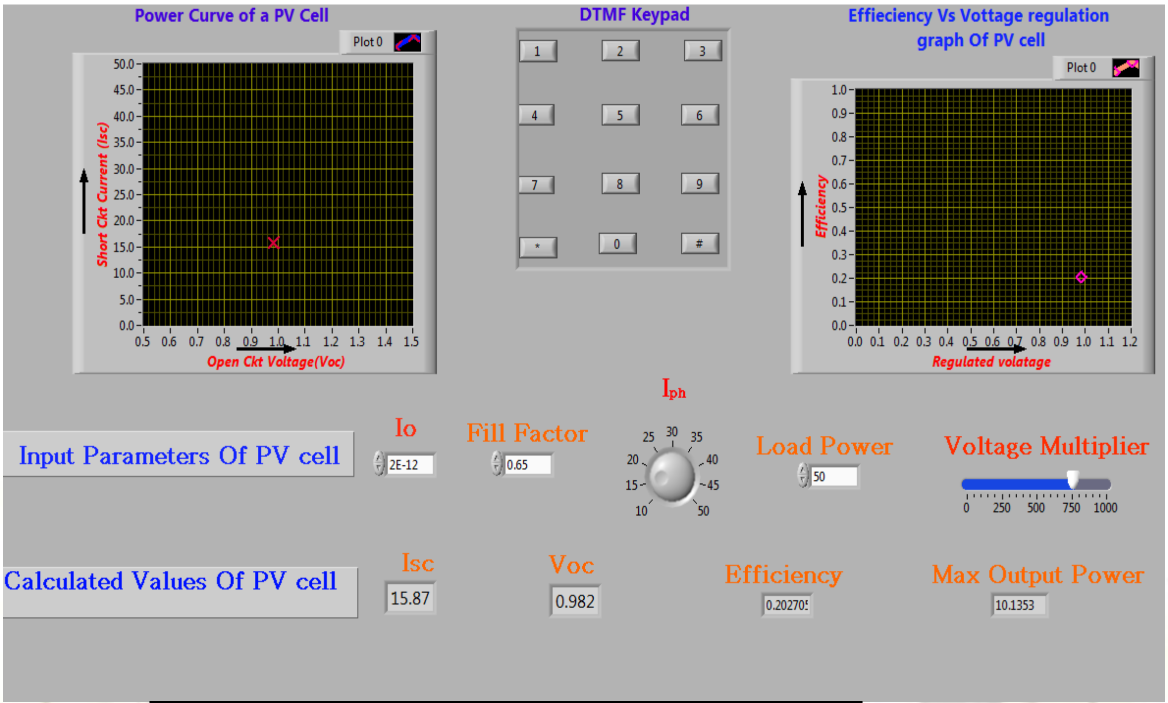


Figure5.7 Lower efficiency during cloudy weather

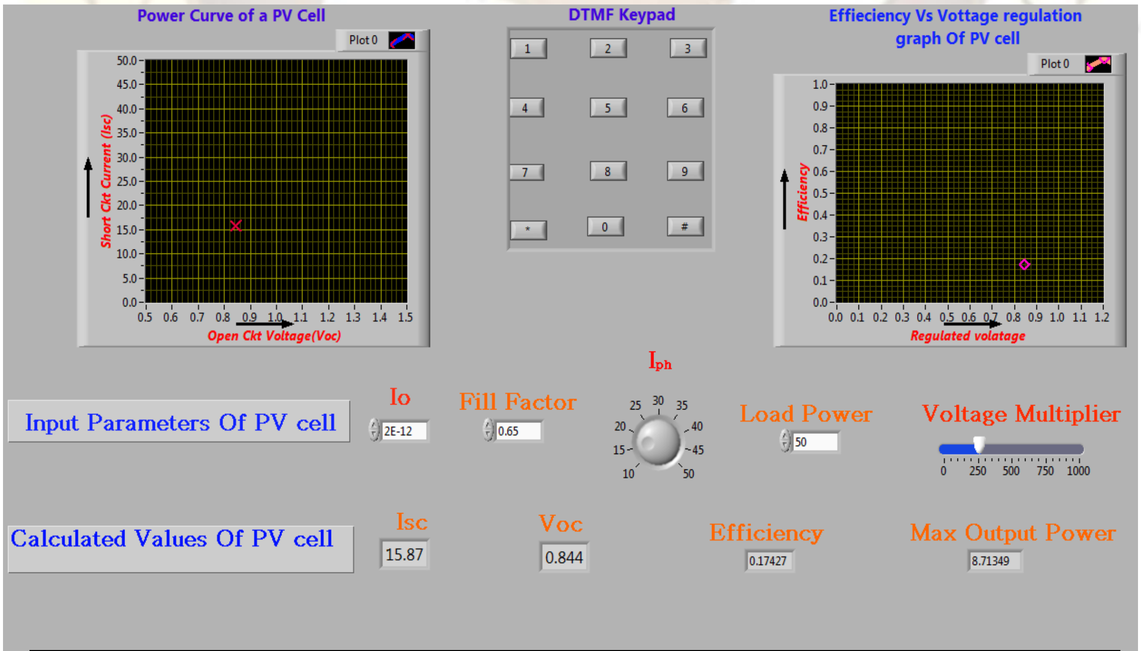


Figure5.8 Efficiency improvement by increasing voltage multiplier value by pressing key 1

keypad when it is connected to remote system. Same DTMF Controller can be used for the purpose of regulating the open circuit voltage (Voc) of a PV cell to improve the efficiency of the cell. Using this method engineers will be able to engineers are able to regulate the open circuit voltage level from the control room in such a way so that the efficiency of cells can be improved as a result the overall PV panel's efficiency can be improved.

One of the limitations of the suggested method is the unwanted noise problem while sending or receiving the DTMF signals during the practical implementation. Highly sensitive tone measurement device has to be chosen to avoid the unwanted noise problem during communication process.

One of the major advantages of the proposed system is same DTMF based keypad can be used to send different control signals to the remote location & total process can be done via a wireless network by using mobile phones.

REFERENCES

[1] Yun Chan Cho and Jae Wook Jeon "Remote Robot control System based on DTMF of Mobile Phone", *IEEE International Conference INDIN 2008, July 2008.*

[2] Coskun and H. Ardam, "A Remote Controller for Home and Office Appliances by Telephone", *IEEE Trans .Consumer Electron. , vol. 44, no. 4, pp. 1291- 1297,November 1998*

[3] C. K. Das, M. Sanaullah, H. M. G. Sarower, M. M Hassan, "Development of a cell phone based remote control system: an effective switching system for controlling home and office appliances" - *International Journal of Electrical & Computer Sciences IJECS Vol: 9 No: 10*

[4] R. Sharma, K. Kumar, and S. Viq, "DTMF Based Remote Control System," *IEEE International Conference ICIT 2006, pp. 2380-2383, December 2006.*

[5] Yavuz EROL, Hasan H. BALIK, Serkan INAL, Duygu KARABULUT, "Safe and Secure PIC Based Remote Control Application for Intelligent Home", *IJCSNS International Journal of Computer Science and Network Security, VOL.7 No.5, May 2007*

[6] M J. Callahan, Jr., "Integrated DTMF receiver," *ZEEE J. Solzd-State Czrcuzts, vol.,1 Sc-14, pp. 85-90, Feb. 1979.*

[7] Suvad Selman, Raveendran Paramesran "Comparative Analysis of Methods Used in the Design of DTMF Tone Detectors", *IEEE International Conference on Telecommunications and Malaysia International Conference on Communications, 14-17 May 2007, Penang, Malaysia.*

[8] R.C. Luo, T.M. Chen, and C.C. Yih, " Intelligent autonomous mobile robot control through the Internet ", *IEEE International Symposium ISIE 2000, vol. 1, pp. 6-11, December 2000.*

[9] KwangYeol Lee; Jae Weon Choi, "Remote-controlled home automation system via Bluetooth home network", *SICE 2003, vol. 3, pp. 2824 – 2829, 2003.*

[10] T. Markvart and L. Castaner, *Practical handbook of photovoltaics fundamentals and applications* (Elsevier, 2003).

[11] L. Castaner, *Modelling photovoltaic systems using pspice* (CRC Press, 2002).

[12] M. D. Archer and R. Hill, *Clean electricity from photovoltaics* (Imperial College Press, 2001).

[13] G. A., "Photovoltaic materials, history, status and outlook," *Materials Science and Engineering: R: Reports, vol. 40, pp. 1–46, January 2003.*

[14] K. Hussein, I. Muta, T. Hoshino, and M. Osakada, "Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions," *Generation, Transmission and Distribution, IEE Proceedings-, vol. 142, pp. 59–64, Jan 1995.*

[15] D. Hohm and M. Ropp, "Comparative study of maximum power point tracking algorithms using an experimental, programmable, maximum power point tracking test bed," *Photovoltaic Specialists Conference, 2000.Conference Record of the Twenty-Eighth IEEE, pp. 1699–1702, 2000.*

[16] Relay Information http://en.wikipedia.org/wiki/Relay.