



Comparative Analysis of Capacitance Finding Techniques of a Solar Cell

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Abstract— Variable capability of the PV module depends on the ability of the photovoltaic cell to be standard. Finding this parameter is not as easy. The finding of capacitance of photovoltaic cell needs high accuracy instrument. Two ways are going to be mentioned during this analysis, one is Electrical phenomenon spectrographic analysis (IS) and alternative one is RLC circuit methodology. The most straight forward methodology for locating capacitance a PV module. The electrical event spectroscopy is the most common way to check the dynamic nature of PV modules. Supported by these methods, the AC parameters, capacitors and dynamic and series registrations of photovoltaic cells will be set. Check out the following signal (Voltage or Current) device. The test device electrical effect will be calculated by taking significant AC voltage and current. The test device electrical effect spectrum will be detected by AC signal frequency variable. Duty equivalent circuit is supported, its components will be determined by capacitance in case of serial fitting method and parallel resistance and photovoltaic cell. Electronic devices are constructed as a load of photovoltaic cells. The ability of photovoltaic cells to detect the frequency of oscillation of gas by menstrual cycle, which happens promptly to connect the electrical device to a photovoltaic cell. By assembling completely different Indicators in photovoltaic cells. The frequency effect on photovoltaic cell capacities has been studied considering the low intensity of capacitance with frequency. This analysis introduces an easy and effective methodology to work out the electrical Capacitance of the photovoltaic cell.

Keywords— Solar Cell, PV Module, RLC Methodology, Impedance Spectroscopy, Renewable Energy.

I. INTRODUCTION

Solar cells are one of the most important sources of renewed energy. Several solutions to measuring the risk of recycling (PV) use as a reproducible power source to respond to pollution control have been developed. Because of current

non-linear voltage (I-V) properties of PV components, it is not easy to install electrical parameters. In the past decade, PV has been transformed as a result of the electronic standards of electric cells. An electrical examination of the units was conducted. DC and AC [1], focused on the electrical parameters in each study. The most widely used technologies for checking the dynamic nature of photovoltaic units are the specifications of the IS-[2] power supply. This protocol supports AC parameters, capacitors, dynamic resistance, and limitations of electric cells. Test Device electrodes react and start from AC voltage. Changing the AC signal, frequency will detect the electrical resistance spectrum. Electrical equivalent circuit is supported, it's series and parallel resistance is determined by theoretical formula and therefore capacitance is determined in case of electric cells. An RLC is designed as a load for circuit electric cells, as it is made by an electrical device. The electrical cell's capability is measured in the frequency of the electrical cells, by adding completely different parameters; the study of electric cell capacitors is done by frequency difference, which reduces the ability to increase frequency.

After reducing the carrier's concentration, the electro cell would be reduced to at least 14 cell capacities after it was radiated [3]. After the hot spots, the capacity of the PV panel will increase[4]. The amount of additional squares in the manner of reproducing energy, in some cases, is considered a practical alternative to common source energy. Photovoltaic technology developed and maturity was cheaper than alternative energy sources. Solar panel power containers require high Power and high efficiency to use high-speed switch load controllers. In order to design an economical and reliable switch loading controller, it is necessary to verify the cell capacity and cell code.

Once the electrical appliance is working while working outside the door, the difference between temperature for the given operator voltage can change the cell or panel operative status. The AC Parameters of cell have been calculated in completely different cell temperatures, in which the dark condition absorption resistant cell bias voltage (forward and

vice versa) changes under qualitative analysis techniques. At any voltages the cell capacitance with temperature would be increased. High Power System is well connected to the load system and attracts it seamlessly. Therefore, the load panel must be forced to provide the battery with continuous power, so that the energy will be generated at a specific level. As such, the electrical cell or panel is necessary to switch between the batteries and therefore the shunt switch is quickly required. The electrical cell is often designed as a parallel RC network. Due to the gift of capacitance in electrical cells, The AC parameters, in particular, the ability of PV cells are a factor of deterioration in the functionality and reliable method of the charging controller. Photovoltaic cell capacitance is the combination of transition and diffusion capacitance. Transition capacitance is on one side of the sudden PN-junction profile. The resistance of solar cell is the combination of dynamic resistance and static resistance.

II. SOLAR CELL CAPACITANCE AND ITS TYPES

Solar cell is a PN junction or we can say series connected PN junctions [5]. It has a photo generated current source which is connected in parallel. A PN junction is a simple diode and diode itself has series and parallel resistance. Solar cell is often characterizing by its capacitance [6]. The capacitance of the cell is directly with area, thus device with massive area can have large capacitance. The photovoltaic cell Capacitance is that the combination of 2 capacitances, one is junction capacitance (C_j) and different is diffusion capacitance (C_d). Junction capacitance is additionally referred to as transition capacitance. the entire Capacitance of a photovoltaic cell is that the addition of each transition and diffusion capacitance. The diffusion capacitance C_d is usually dominant on the far side $V_d=0.8V_{oc}$, wherever V_{oc} is that the electrical circuit voltage of the electric cell. The junction or transition capacitance is dominant over a voltage vary of $0-0.7V_{oc}$ and in reverse bias. If the voltage vary is confined to $V_d < 0.7V_{oc}$ then the electric cell capacitance is given by its junction capacitance only.

A. Junction Capacitance.

Junction capacitance could be a capacitance of PN junction diode once it's connected in reverse biased. In traditional parallel plate condenser conductor permits the physical phenomenon, there's medium between parallel conducting plates that doesn't permit physical phenomenon. once voltage is applied against it, charges began to accumulate on electrodes and voltage won't move through the medium however the medium can permit field to flow although it once vast range of charges accumulates on electrodes, electrodes stores the charge and therefore the ability to store charge is understood as capacitance.[6]

$$Q = CV \quad (1)$$

Arranging for C

$$C=Q/V \quad (2)$$

C is that the capacitance, Q is the charge and V is the voltage. When reverse voltage is applied across PN Junction, regions P and N behaves as electrodes these two regions have less resistance, depletion region is made that act as stuff medium with high resistance. These 2 regions permit the charge to store in an electrical field. The power of storing charge is named capacitance that is termed as PN junction diode as junction capacitance.

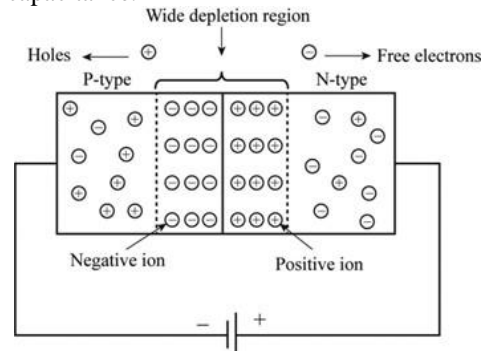


Figure 1. PN Junction diode under reverse condition

When reverse voltage is applied across PN junction diode, the holes from P kind region moves far away from the junction and electrons from N kind region move far away from the junction thus as a result the dimension of the depletion region can increase. The depletion region act as a material medium and stores electrical phenomenon. once voltage across the junction will increase the depletion region will increase however the dimensions of P and N region decrease that decrease the flexibility of storing charge.

The diode with larger depletion region and large P and N regions will store additional electrical phenomenon. The diode with broad depletion region and little P and N regions will store less electrical phenomenon. So the voltage which is applied is reciprocally proportional to junction capacitance beneath reverse bias condition

$$C_j = A/W \quad (3)$$

C_j is the junction capacitance, A is the area of P and N regions and W is the width of depletion region.

B. Diffusion Capacitance.

When PN Junction diode is connected in forward bias the capacitance is made, this capacitance is thought as diffusion capacitance and is denoted as C_d . This capacitance is way bigger than the junction capacitance. Throughout this biasing the potential barrier r depletion region is reduced and also the P and N regions will increase. The charge carriers move far away from the junction and so recombine. The density of charge carriers is higher close to the junction and decays once the gap will increase. So during this case charge is holding on in each side of the junction and varies with applied potential. Thus modification to blame with reference to the applied voltage lead to capacitance that is termed diffusion capacitance. Diffusion capacitors are the charge carrier transport between

the 2 terminals of the device. Once current is flown through conductor thus there's some charge within the method of transit during a specific moment, the present changes to completely price once the voltage is modified to a special value, thus different quantity of charge are going to be transit in numerous circumstances. The full amendment is quantity of charge transit divided by the full voltage inflicting its diffusion capacitance [7].

$$C_d = (dQ/dV) t \tag{4}$$

"t" is the transit time, dQ is the change in charge and can be represented in form of voltage and current, dV is the change in voltage [8].

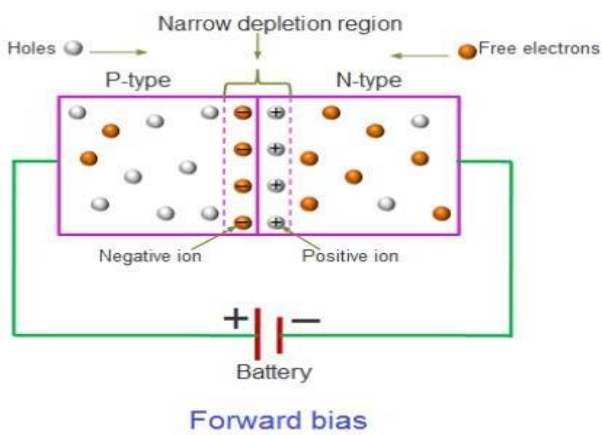


Figure 2. PN Junction diode under forward bias

III. METHODS AND TECHNIQUES

A. Impedence spectroscopy.

Almost everyone knows the definition of Electrical Resistance. It is ability of electrical circuit to stop the flow of electrical current and can be shown by relation with V and I.

$$R = V/I$$

The real world contains Electrical elements which show much more complex behavior. These elements force us to abandon the concept of resistance and its parallel we use impedance. [9]. The efficiency of solar cells can be measured using frequency domain technologies. Frequency domain uses a small signal during the technique operation, calculating criteria and returning values. In cellular technology, a cellular voltage is transmitted from a small circuit to an open circuit, so the value of the solar cells is a combination of short circuits and open circuits. There are some advantages and disadvantages for this domain to measure solar domains. In recent studies effectiveness of a solar cell is reduced. [10][11]. Therefore, an experimental sample was developed to find the strength of the solar cell using the impedance spectroscopy technology.

- Principle of impedance spectroscopy:

Impedance Spectrum Analysis may be featured with some or all electrical resistive measurement and analysis of connected functions. Once the plotting is complete, plotting has been completed in the complex plane during this setup, and then the device's shortest signal model is explained. In impedance spectroscopic analysis, the complicated impedance that is $(R + jX)$ of a tool that is below take a look at is measured. This measure is completed directly within the frequency domain; sizable amount of frequencies is applied to it always 2 or 3 decades. During this technique a strictly curved voltage is applied, this voltage can have completely different frequencies, in doing so amplitude is measured of the device, real and imagined elements of the ensuing current of that frequency is measured. The ratio of the applied voltage and also the ensuing current is set which supplies the electrical resistance each real and imaginary part of a complex number of the device below take a look at. A plot is drawn between R and JX on a Fancy Plane between R and JTX, which provides an electrical resistant spectrum of equipment for different frequencies. The resultant circuit parameters are calculated as a result. The resistive R_p and the electrical equipment are attached in the C_p parallel electrical resistance spectrum. Touching the basic part of this spectrum can be the plane figure of the fourth quadrilateral related to the real radius and if the radius is removed from the original if the radius is $R_p / 2$. If the network line shows resistance availability. The shape of this spectrum depends on the device's surrounding parameters, which changes the parameters depending on the frequency and allows you to configure the variable parameters by configuration [31]

- Experimental Setup:

Experimental structure Electromotive Interface (ECI), Frequency Research Analyzer (FRA), Laptop, Solar Cell, Figure 4 , which is measured capacitance.

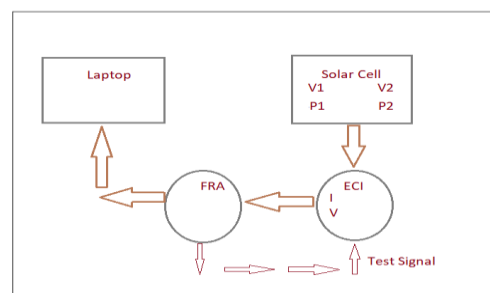


Figure 4. To measure Capacitance of solar cell by experimental Setup.

- The experimental setup is designed in the figure shown above. In these step voltages V_1 and V_2 are measured between 2 points of solar cell that is P_1 and P_2 .
- The solar cell is then connected with ECI which further connect to FRA.

- c) Voltages between points P₁ and P₂ are measured with meter and the resistance is set from 0.1 to 5k ohm.
- d) The ECI gives stable voltage to testing unit.
- e) Test signal of sinusoidal waveform is given to the ECI from FRA for testing purpose. This signal is of varying frequency. i.e 10^3 to 10^7 Hz. Testing signal of <10mV is applied to avoid distortion.
- f) Personal laptop is connected to the FRA for simulation purpose.
- g) FRA gives the real and imaginary outputs by varying the frequency.
- h) The time (T) is noted when signal is applied.

• Testing Setup:

- i) The frequency of 10Hz to 100Hz is used in conjunction with an electrical voltage less than 10mV
- j) The real and imaginary breaking parts of the grid are measured from 1Hz to 10 kHz. (28).
- k) Similar bandwidth is used and negative Y-Axis.
- l) Impedance spectrum consists of two trials.
- m) The first parameter of the RC scheme is calculated for the large semiconductor. In point "C" the imaginary (Z) size is equal to the actual (Z) size that is, R3.
- n) The spectrum 2 is 5 kHz, and the X3 is 7.28 kΩ
- o) Parallel to this parallel component X3, the parallel capacity of Ceq is 9.98nF. For similar frequencies, the serial bandwidth values are taken over the measured data and calculated for values corresponding to R3, X3, and Ceq. These values are presented in Table 1.
- p) More precisely, the above figures will be at the maximum value of X3 interactions.

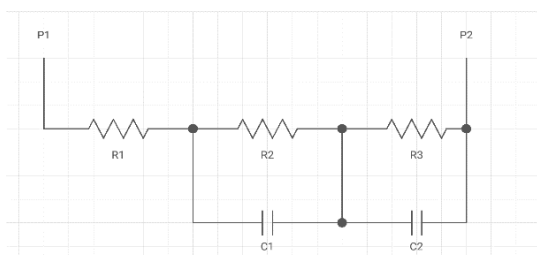


Figure 5. Equivalent Circuit

Table 1. Calculated values of R₂, X₃, and C_{eq} for different frequency.

Frequency (Hz)	R ₃ (kΩ)	X ₃ (kΩ)	C _{eq} (μF)
1	6.80	5.25	9.98
5	7.28	7.28	10.2
10	8.16	9.33	11.3

B. RLC Resonance Method:

This method is based on the behavior of the RLC (Resistor Inductance Capacitor) schemes. An inductance is used as a variable load for solar cells. The method can be used in light conditions, starting at 1 W / m³. The simulation is done in Orcad PSpice 9.1 version.

• Connection Behaviour

RLC connection is an electric program with a resistor (R), Inductor (L) and Capacitance(C). It's serials or parallel. The name of the switch is received from the letters used in the components of this network, where the order of the components differs from RLC. The Radio transmitters and television equipment are used to select radio frequency. A turn on this role is often known as long term relationship. The RC connection can be used as a low pass filter, or high pass filter. For example, tunes application group transition filtering is an example. The RCL filter is termed a second class circuit. This means that Communication voltage or electrical circuit can be explained in the differential equations in a secondary order. You can add three mode modules, R, L and C into different systems. The three components of the parallel range and the three components are more convincing and understandable to analyze the most effective. However, there are other arrangements, some actual practical schemes. One of the frequently encountered problems is the resistance of induct. Inductors are usually constructed with metal bombs whose resistance are usually not desirable, but often has a significant impact on the connection.Ac and DC equivalent is shown in figure 6 and 7.

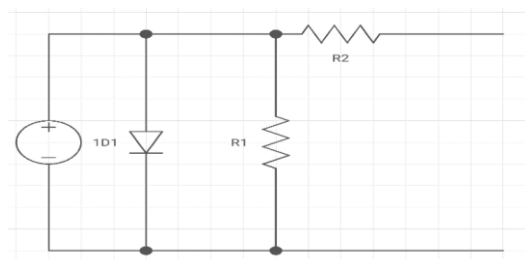


Figure 6. DC Equivalent of solar cell

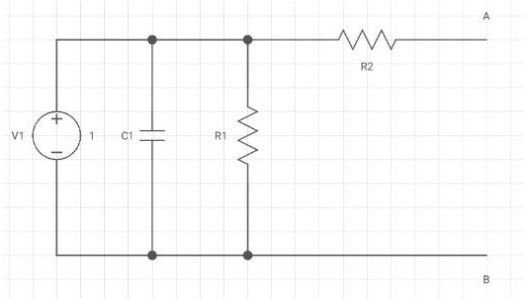


Figure 7. AC Equivalent.

C_1 is equal to the parallel circuit of diffusion and junction capacitance while R_1 is equal to the parallel circuit of Shunt and diffusion resistance. V_1 is the voltage applied against the cell.

- .Mathematical Form

$$V = V_p \sin(\omega t + \varphi) \quad (5)$$

In the above equation at resonance condition we have a resonance frequency which is given by equation 6.

$$\omega = \sqrt{(\omega_0^2 - \beta^2)} \quad (6)$$

Above equation is used for finding resonance frequency at amplitude of V_p , φ is the phase angle in the very first condition of the resonance frequency. The third important factor is the damping co-efficient β . This factor depends on capacitance, consequently, ω_0 is the natural frequency which show in equation 7.

$$\Omega_0 = 1/\sqrt{LC} \quad (7)$$

Where L is the inductor connected we will use inductor of different values in this thesis to find capacitance, while C is the capacitance of solar cell attached. β shown in the resonance frequency equation is the damping ratio co-efficient. For this method to be applied damping co efficient must be less than the natural frequency of the test setup to get an underdamped oscillation. We will take the logarithmic decrement 'δ' of any two successive peaks at time t and T and this logarithmic decrement is generally between two peaks which can be shown as follows:

$$\delta = \ln(x(t)/x(t + nT)) \quad (8)$$

In the above equation $x(t)$ is the peak at time t , $x(t + nT)$ is the other peak with n number of peaks. In this method we take $n=1$, now taking natural log of the above equation:

$$\begin{aligned} \delta &= \ln x(t)/x(t + T) \\ \delta &= \ln x e^{-\beta t} / x e^{-\beta(t+T)} \\ \delta &= \ln e^{\beta T} \end{aligned}$$

$$\delta = \beta T \quad (9)$$

Where in the above equation $T = 2\pi f$.

Capacitance is calculated at $f = \omega / 2\pi$, knowing the cost of the coil induction and the determinant frequency, as well as the resulting power fluctuation. Putting value of T in Equation 9.

$$\begin{aligned} \delta &= \beta \times (2\pi f) \\ \beta &= \frac{\delta}{2\pi f} \end{aligned} \quad (10)$$

Putting values of β in above equation of resonance frequency:

$$\omega^2 = \omega_0^2 - \left(\frac{\delta}{2\pi f}\right)^2 \quad (11)$$

$$\text{As } \omega^2 = 1/LC$$

$$\text{so } \omega^2 = \frac{1}{LC} - \left(\frac{\delta}{2\pi f}\right)^2 \quad (12)$$

So by Re Arranging for C we get

$$C = \frac{1}{L(\omega^2 - (\frac{\delta}{2\pi f})^2)} \quad (13)$$

$$\text{As } \omega = 2\pi f, > \delta = \beta 2\pi f$$

By putting values of ω and δ we get:

$$C = \frac{1}{L(2\pi f + \beta 4\pi^2 f^2)} \quad (14)$$

Above Equation 14 will be used for finding capacitance of cell at different frequency.

IV. RESULTS

A. Capacitance Vs Inductance

Taking different values of L keeping frequency 50 Hz and $\beta=0.2$ we found different values of C in the Table 2, the trend can be seen in figure 7.

Table 2. Capacitance with Different Inductance

L [H]	C [nF]
50	998
70	713
90	554
100	500

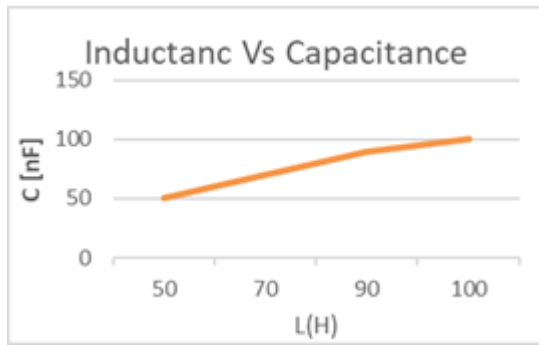


Figure 7. Plot Capacitance against Inductance.

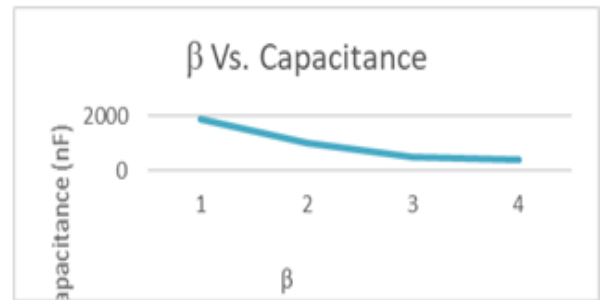


Figure 9. Plot Capacitance against β

B. Capacitance vs Frequency

By keeping inductance value constant we can take different values of frequency to study the behavior of capacitance with the frequency. Now taking Inductance Value $L=50\text{H}$ and $\beta=0.2$ we change frequency from 50 kHz to 100 kHz. We will take different interval under this range. Results are shown in Table 3 and plot can be seen in figure 8.

Table 3 Capacitance with different frequency

β	Capacitance (nF)
0.1	1906
0.2	998
0.4	500

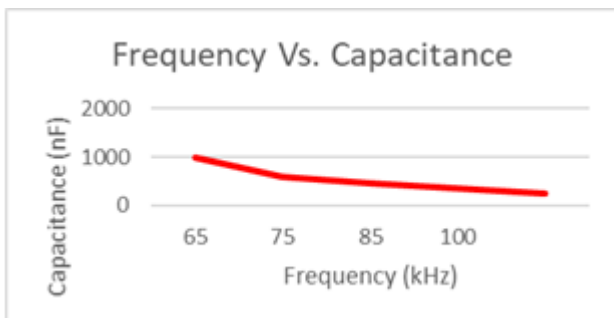


Figure 8. Plot Frequency Vs. Capacitance.

C. Capacitance Vs β

Now we take different β values ranging from 0.1 to 0.8 but it should be less than resonance frequency. Keeping inductance 50H and frequency 50 Hz. Again we will use Equation 14 results are shown below in Table 4 and plot can be seen in figure 9.

Table 4. capacitance with Different β

β	Capacitance (nF)
0.1	1906
0.2	998
0.4	500

V. PRACTICLE DEMONSTRATION

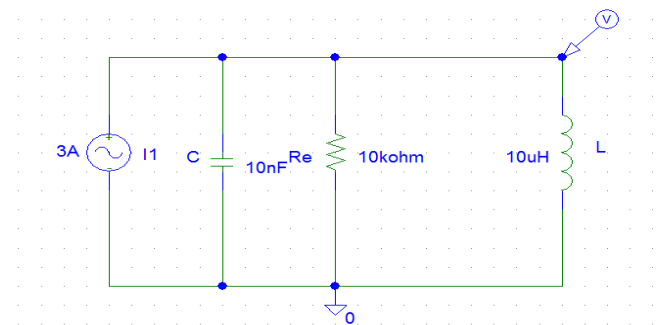


Figure 10. Experimental setup

Experimental setup is being shown in figure 10. Equivalent Circuit is drawn in simulation software Orcad Pspice 9.1 version. Transient response of the above circuit is simulated from 0 to 10ms. The current source is set on 3A. Current and voltage waveform is created which is shown below.

By Changing the values of Capacitance and frequency we get different values of current across inductor which act as a load and capacitor. I_1 is set to different values the results are shown in the table Table 5.

Table 5. I_1 with frequency and Capacitance.

Frequency [kHz]	I_1 [A]	Capacitance [nF]
10	3	10
35	12	11.2
65	18	11.8
95	25	12.1

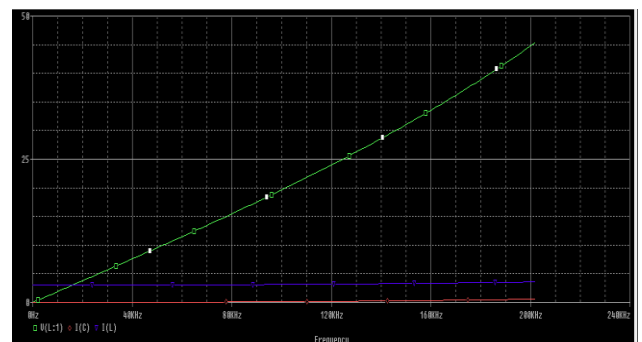


Figure 11. Capacitance Against frequency and Current.

We changed the values of inductor in the circuit from $10\mu\text{H}$ to $50\mu\text{H}$ with the changing frequency. By doing so we get different values of capacitance.

Table 6. Capacitance with F and L.

Frequency [kHz]	Inductance [μH]
10	10
35	25
65	35
95	50

Table 6 values can be shown in figure 12.

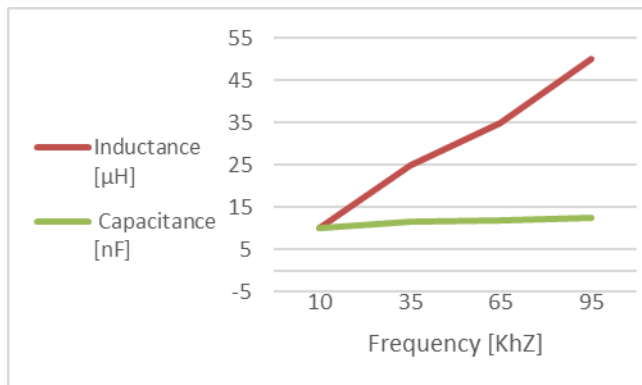


Figure 12. Inductance, Capacitance, Frequency Plot

The changing inductance and frequency gives the same result as show in the Table 6.

CONCUSLION

The capacitance introduces a dynamic parameter of PV components, and can be analyzed as PV modules can provide quality and health information. In this research I am using solar cells and PV. I suggested the RLC method that guarantees the efficiency of the panels. Continuous continuity in this method and open circuit points, L1, is believed to be connected to a solar cell. Method which is very easy to work with is RLC and the external signal which is required in IS method is not important in RLC method, which reduces processing costs. The value of the function used by this method is based on the results based on repeated spectral analysis. Various indicators, solar cells, and photovoltaic panels can be used in many frequencies, approximately one (10-50 kHz). Solar cell capacitance increased from $10\mu\text{F}$ to $12.5\mu\text{F}$. In addition, the results indicate an increase in the ability to learn solar cells. In order to minimize the minimum depth of collapse, the β value will be always less than the resonance frequency ω . In addition, file-assisted installation methods must be used to generate capacity at different frequencies. The calculation of solar cell capacitors has a precise impact on the urgency and accuracy of genetic frequency stability. The advantage of the IS method is that, this method provides information about all three dynamic parameters, but a large loss of this method means that it requires an external signal that must be included in the device under test. It requires an external channel capable

of producing signals whose purpose can be used for testing. The cost of these devices being used is high, when the test is made in light conditions.

REFERENCES

- [1] Chan, D.S.H.; Phillips, J.R.; Phang, J.C.H. A comparative study of extraction methods for solar cell model parameters. *Solid-State Electron.* **1986**, *29*, 329–337. [CrossRef]
- [2] Kumar, R.A.; Suresh, M.S.; Nagaraju, J. Silicon (BSFR) solar cell AC parameters at different temperatures. *Sol. Energy Mater. Sol. Cells* **2005**, *85*, 397–406. [CrossRef]
- [3] Kim, K.A.; Seo, G.S.; Cho, B.H.; Krein, P.T. Photovoltaic Hot-Spot Detection for Solar Panel Substrings Using AC Parameter Characterization. *IEEE Trans. Power Electron.* **2016**, *31*, 1121–1130. [CrossRef]
- [4] Rauschenbach. S. *Solar Cell Design Handbook*. Princeton, NJ: Van Nostrand, 1980.
- [5] Hailing Wang, Ten-Lon Chen, and Gennady Gildenblat, Quasi-static and Nonquasi-static Compact MOSFET Models <http://pspmodel.asu.edu/downloads/ted03.pdf>
- [6] Mary Anne Tupta, “Evaluating Performance of Photovoltaic Cells” Keithley Instruments, October 2010.
- [7] Mary Anne Tupta, “Evaluating Performance of Photovoltaic Cells” Keithley Instruments, October 2010
- [8] William Liu (2001). *MOSFET Models for Spice Simulation*. New York: Wiley- Interscience. pp. 42– 44. ISBN 0-471-39697-4.
- [9] <https://www.gamry.com/application-notes/EIS/basics-of-electrochemical-impedance-spectroscopy/>
- [10] 1R. A. Kumar, M.Sc. ~Eng! thesis, Indian Institute of Science, Bangalore, India, 2000.
- [11] R Mac Donald, W.B Jhonson, *Impedance spectroscopy*, wiley Newyork,1987.

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