



# Modelling of Maximum Power Point Tracking of Photovoltaic Module Using Incremental Conductance Method

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## Abstract

Solar energy is of great interest since the beginning of human existence because of its vitality for all living organisms. Once it started to be converted to electrical energy this interest shifted its direction. To date, there have been different types of power electronics methods to harvest the maximum energy from the photovoltaic module. In this study incremental conductance algorithm was summarized and this method for maximum power point tracking was modified for average weather conditions of central Anatolian summer. Maximum power point tracking (MPPT) algorithm provides load matching with the maximum power locus of the photovoltaic (PV) source and in this method PV power remains at its maximum level for different environmental factors such as irradiation and temperature. In incremental conductance method, derivative of power with respect to PV voltage is zero at maximum power point, is negative for right side of the peak and positive for left side of the peak. If this derivative is zero, there is no need for change. However, if it is negative the module voltage needs to be decreased; otherwise it needs to be increased. Increasing or decreasing the voltage depending on the voltage and current measurement was realized by turning on/off the MOSFET which is connected to the DC-DC converter circuit. The proposed model was implemented in the simulation environment and the results were obtained for future experimental verification.

**Keywords:** Solar Energy, Photovoltaic, Solar Cell, MPPT, Incremental Conductance.

## Artımsal İletkenlik Yöntemini Kullanarak Fotovoltaik Modülün Maksimum Güç Noktası Takibinin Modellenmesi

### Öz

Güneş enerjisi, tüm yaşayan organizmalar için önemi nedeniyle insan varoluşunun başlangıcından beri büyük ilgi görmektedir. Bu alaka güneş enerjisi, güneş paneli yardımıyla elektrik enerjisine dönüştürülmeye başladığında ilgi başka yöne evrildi. Bugüne kadar, fotovoltaik modülden maksimum enerjiyi elde etmek için farklı tiplerde güç elektroniği yöntemleri olmuştur. Maksimum güç noktası izleme (MPPT) algoritması, fotovoltaik (PV) kaynağın maksimum güç lokusu ile yük eşleşmesi sağlar ve bu yöntemde PV gücü, ışınlama ve sıcaklık gibi farklı çevresel faktörler için maksimum seviyesinde kalır. Bu çalışmada ise MPPT algoritmalarından artımsal iletkenlik tekniği özetlenmiş ve bu maksimum güç noktası izleme yöntemi Orta Anadolu yaz mevsiminin ortalama hava koşulları baz alınarak simüle edilmiştir. Artımsal iletkenlik yönteminde, gücün PV gerilimine göre türevi maksimum güç noktasında sıfır, tepenin sağ tarafı için negatif ve tepenin sol tarafı için pozitifdir. Bu türev sıfır ise herhangi bir değişikliğe ihtiyaç duyulmaz. Ancak negatif ise modül voltajının azaltılması gerekir. Eğer pozitif ise daha da henüz güç tepe noktasına ulaşmadığı için artırılması gerekir. Gerilim ve akım ölçümüne bağlı olarak gerilimin artırılması veya azaltılması, dönüştürücü devreye bağlı olan MOSFET açılıp/kapatılarak gerçekleştirildi. Önerilen model simüle edildi ve simulasyondan elde edilen sonuçlar gelecekte yapılması planlanan deneysel çalışma için ümit vericiydi.

**Anahtar Kelimeler:** Güneş Enerjisi, Fotovoltaik, Güneş Pili, Maksimum Güç Noktası İzleyici, Artımsal İletkenlik.

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## 1. Introduction

Photovoltaic (PV) energy is growing rapidly especially in last three decades and in the globe and it might be a game-changing technology to meet the high-energy demand around the world. Some of the popular utilization of PV energy generation can be listed as streetlights, satellites, telecommunications, heating water, feeding water pump and grain drying for agriculture, water desalination. (Sampaio et al., 2017) Even though solar energy research has lots of benefits such as being environmentally friendly, generating energy on the site without requiring the transfer, low cost energy generation because of solar abundance it is still coming across different constraints like low efficiency of solar module, high cost at the installation and difficulty of financing this technology and institutional restrictions (for instance lacking of infrastructure and qualified technical personnel). (Kabir et al., 2018). The low efficiency constraint can be overcome if the maximum power can be harvested from the PV module. Maximum power point tracking (MPPT) algorithm provides load matching with the maximum power locus of the PV source and in this method PV power remains at its maximum level for different environmental factors such as irradiation and temperature.

To date there have been lots of studies about MPPT and these studies compared the methods with each other by taking complexity, cost, convergence speed, required sensors, implementation hardware and the effects of environmental parameters into consideration (Nabil et al., 2017). One algorithm called the perturb and observation to increase the efficiency of photovoltaic module is based on measuring the power after perturbing the operating point of PV module and changing the rated voltage depending on the increase or decrease of the power measurement (Mohammed et al., 2011). Another method to use the PV module more efficiently is constant voltage algorithm. This method benefits the phenomenon of peak power voltage of the PV module is proportional with open-circuit voltage of the module (Zhihao et al., 2009).

Incremental conductance algorithm was employed in this study to harvest the maximum energy from the photovoltaic module. As expected, derivative of power with respect to PV voltage is zero at maximum power point, is negative for right side of the peak and positive for left side of the peak. If this derivative is zero, there is no need for change. However, if it is negative the module voltage needs to be decreased; otherwise it needs to be increased (Azadeh et al., 2011, Sivakumar et al., 2015, Kok Soon et al., 2014]. In this algorithm, that phenomenon is exploited. Most of the studies applying incremental conductance method employed constant step size for MPPT while some used varying step size in this method. Therefore the accuracy and robustness of the system are mostly related to the step size selection. If larger step size is used PV module responds faster but this might cause instability because of the big perturbations. On the other hand, using small step size decreases the oscillation. However, operating the PV module at MPP will take some time since the tracking velocity is slower in this case (Abdelhamid et al., 2016).

## 2. Material and Method

### 2.1. Method

#### 2.1.1. Equations and Inequalities

To explain the algorithm the following equations and inequalities are provided. If the module is run on maximum power point the derivative of power respect to the voltage needs to be equal to zero:

$$\frac{dP}{dV} = 0 \quad (1)$$

If the operating point is on the right side of maximum power point:

$$\frac{dP}{dV} < 0 \quad (2)$$

If the operating point is on the left side of maximum power point:

$$\frac{dP}{dV} > 0 \quad (3)$$

Since the power is voltage times current the equation (1) can be rewritten as:

$$\frac{dI}{dV} = -\frac{I}{V} \quad (4)$$

Similarly, inequalities (2) and (3) can be rearranged as follows:

$$\frac{dI}{dV} < -\frac{I}{V} \quad (5)$$

$$\frac{dI}{dV} > -\frac{I}{V} \tag{6}$$

**2.1.2. Algorithm and Modelling**

Taking the equations and inequalities into account the flow chart (Jae Ho et al., 2006) in Figure 1 was employed for the incremental conductance algorithm in the simulation environment. In this study the algorithm was modelled and simulated in Matlab Simulink. The derivative of power was calculated based on the voltage and current measurements at the output of PV array (M6L60-260, Alfasolar, Turkey). The reason to select this array for the simulation environment is because of having this PV module in hand and being able to use it for experimental studies in the future.

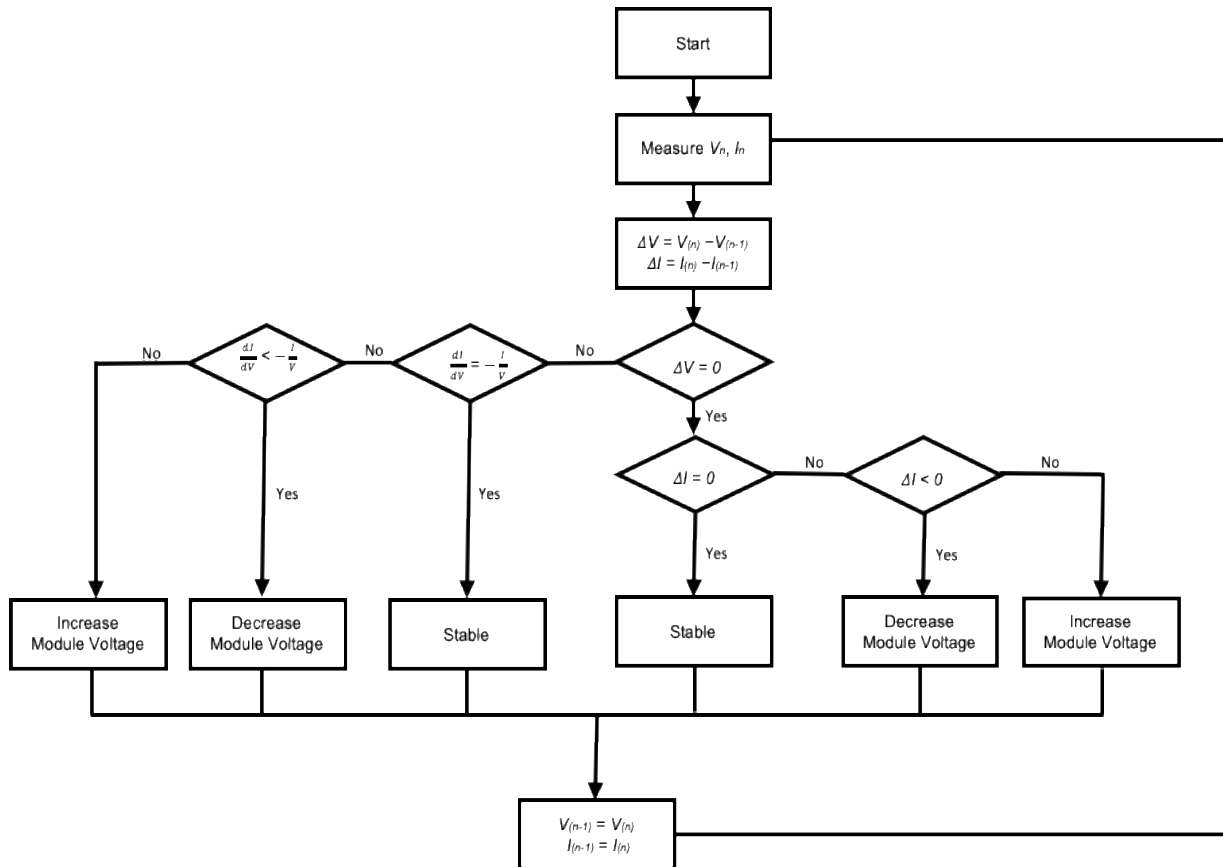


Figure 1. Incremental Conductance Algorithm Flow Chart

**3. Results and Discussion**

Incremental conductance algorithm has shown better results when compared to the other methods such as perturb and observation, constant voltage, etc. The reason to select this algorithm as the MPPT method in this study to harvest the maximum energy from the photovoltaic module is because of easy to observe the current and voltage on the module. Increasing or decreasing the output voltage depending on the voltage and current measurement was realized by turning on/off the MOSFET which is connected to the PV circuit. As shown in Figure 3 A&B the generated voltage at the model output was able to track the simulated solar irradiance in a robust manner. The simulation results were satisfactory for forecasted future research which will be applying of the algorithm to real PV module and obtaining experimental results with the proposed algorithm.

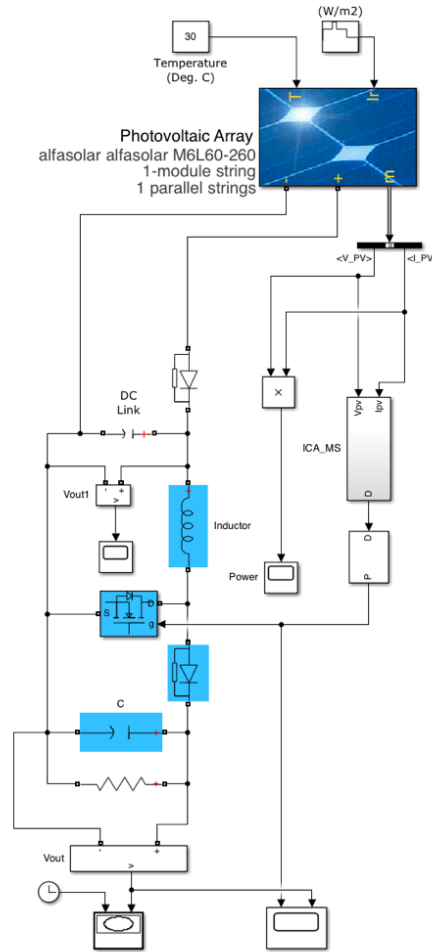


Figure 2. Simulink Model for Incremental Conductance Algorithm

As shown in Figure 3 A&B the generated voltage at the model output was able to track the simulated solar irradiance in a robust manner (even though there are small spikes at irradiance variations the output voltage is still able to track the input power). The simulation results were satisfactory for forecasted future research which will be applying of the algorithm to real PV module and obtaining experimental results with the proposed algorithm.

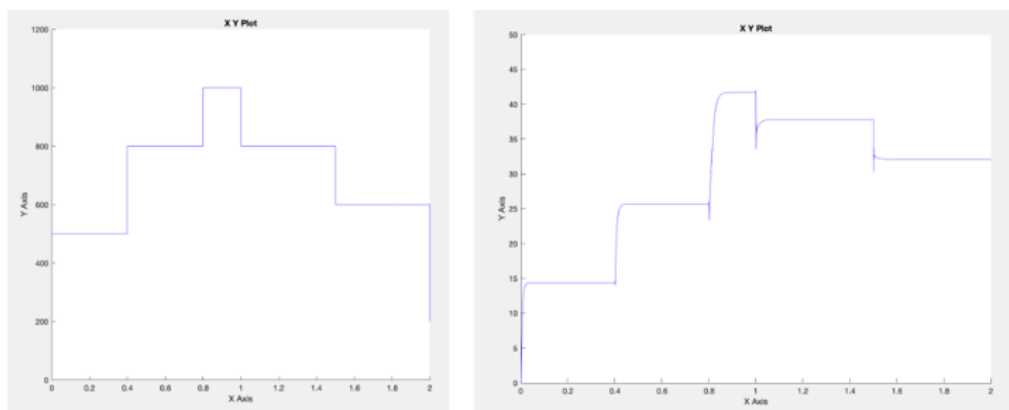


Figure 3 Irradiance ( $W/m^2$ ) values over time (s) graph (left) B Output voltage (V) of simulated model over time (s) graph (right)

#### 4. Conclusions and Recommendations

In this study incremental conductance algorithm as one of the MPPT methods to yield the maximum efficiency of photovoltaic module was summarized. The temperature and irradiance values used are based on the average central Anatolian summer. While applying the algorithm the step size is optimized to track the input power in a stable and relatively slow way. The result obtained by the help of simulated model is very promising for future research, and the next phase of the study will be applying the algorithm to real PV module and comparing the results with the simulation.

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