Optimization of tilt angle of a solar collector in Medan city using genetic algorithm

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Abstract. Solar energy is one of the renewable energy resources that is not limited in its use and it does not cause pollution. One form of solar energy utilization that is often found is to produce electricity with the use of photovoltaics or solar panels. The main problem with solar energy is the instability of power which generated by the solar panels because it depends on the sunlight intensity which accepted by the solar panels. The intensity of sunlight received by the solar panels can be maximized by installing solar panels with a right angle so it will be obtained the maximum output power. In this study, the optimization of the slope angle of solar panels will be analysed using the Genetic Algorithm method. The results obtained are the optimal optimum slope of the panel from January, February, March, April, May, June, July, August, September, October, November and December are 53.839°, 55.121°, 53.938°, 53.442°, 54.398°, 53.441°, 53.009°, 52.933°, 54.709°, 57.055°, 57.169°, 54.632°.

1. Introduction

Solar energy now plays an important role due to the limited use of fossil fuels. The increase of the energy consumption in addition to reducing the emission of pollutants into the atmosphere by using renewable energy resources. Kabir et al concluded, only three renewable energy resources (i.e., biomass, geothermal, and solar). Of these three, solar energy has the highest global potential since geothermal sources are limited for a few locations and the supply of biomass is not ubiquitous in nature [1,2]. The factors that influence solar radiation pass through the Earth's atmosphere are altitude, geographical location, slope, azimuth angle, time (time of day) [3].

The geographical condition is very important for implementing a solar technology. Balaka et al concluded, A position close to the equator can bring many benefits to the province in obtaining solar energy radiation [4]. A. Rachman [5] studied about optimization of solar energy technology based on position adjustment monthly photovoltaic position in southeast Sulawesi. The purpose of this study is to optimize solar PV technology in Southeast Sulawesi using the optimum tilt angle and the direction of the solar panel based on time adjustment. Handoyo et al [6] investigated the optimal tilt angle of a solar collector in Surabaya. They maximize the angle of incidence of beam radiation on a surface or collector which is located in Surabaya with the latitude 7.2° of the South.
Genetic Algorithm is a method to measure the best value to solve optimization problem based on natural selection in a population. According to Messac [7], there are two specific ways to optimize using genetic algorithm: (a) Using command from the optimization application, such as optimtool, (b) Making 3 Matlab file that contains programming code. Talebizadeh et al [8] predict the optimum slope and surface azimuth angles using the Genetic Algorithm. The study was the focus on determining the optimum angle and the input energy gain for hourly, daily, monthly, seasonally, yearly for Iran. The results show that the daily, monthly and yearly optimum surface azimuth angle for receiving the maximum solar energy is zero.

Recently, our laboratory is developing an optimum design for the solar collector that suitable for Indonesia climate. Several related studies have been reported on the literature [9 – 20]. One of the important parameters for the solar collector is tilt angle. The objective of this study is to explore the effect of the tilt angle of a solar collector. The solar collector will be tested by exposing to solar irradiation in Medan city of Indonesia. The results are expected to provide the necessary information on development high-performance solar collector that suitable for Indonesia climate.

This paper focuses on the optimization of tilt angle for monthly in Medan, especially in the magister of mechanical engineering at the University of North Sumatera which has a latitude position 3.43°LU and longitude 98.44°BT at an altitude of 37.5 meters above sea level. From the three parameters, we can obtain the zenith and azimuth angle value will be known from 09.00 AM to 16.00 PM then executed using Genetic Algorithm.

2. Methods
In this study, a genetic algorithm is used to find the optimal angle of the solar panel by following the algorithm cycle by David Golberg [21]. The flow chart of the Genetic algorithm by David Golberg can be seen in Figure 1. The figure shows that the genetic algorithm cycle starts by determining the initial population that will be processed. Then, evaluate the fitness value that will be used as a reference to obtain optimal values. Then, the obtained optimal value will go through the selection process to get a good parent. The parent will go through the cross-over and mutation process to obtain a new population. The process will be looped until it gets the most optimal value.

![Figure 1. Genetic Algorithm cycle by Golberg [21]](image)

In a solar collector there are several types of angles can be defined as shown in Figure 2. They are angle accident, azimuth angle, zenith angle, etc. All of these angles can affect the amount of solar radiation that received by the solar collector.
In this simulation, the optimal tilt angle can be obtained by the following equation [22].

\[ \beta = \tan^{-1}\left[\tan \theta_z \cos \gamma_s\right] \]  

(1)

Where \( \theta_z \) and \( \gamma_s \) is defined as Zenith angle and Azimuth angle, respectively. The Zenith angle and Azimuth angle is defined by equation (2) and equation (3), respectively.

\[ \theta_z = \cos^{-1}\left(\cos \phi \cos \delta \cos \omega + \sin \phi \sin \delta\right) \]  

(2)

\[ \gamma_s = \text{sign}(\omega) \cos^{-1}\left(\frac{\cos \theta_z \sin \phi - \sin \delta}{\sin \theta_z \cos \phi}\right) \]  

(3)

In the above equation, \( \delta \) is declination angle and calculated by the below equation.

\[ \delta = 23.45 \sin \left(360 \frac{284 + n}{365}\right) \]  

(4)

Where \( n \) is the number of the day in the year.

### 3. Results and Discussions

By using the algorithm shown in Figure 1 the optimum tilt angle for location in Medan city has been estimated. The result is shown in Figure 3. The figure shows the optimal average angle from January to December. It can be seen that there are fluctuations in the average of monthly optimum tilt angle due to the annual solar motion. In January, February, September, October, November, and December the sun lane in the southern part of the earth so the collector had to be directed to south, while in March, April, May, June, July, and August the sun was in the northern part of the earth so the collector had to be directed to North. It is clear that the optimum tilt angle varies from 52.93\(^\circ\) to 57.16\(^\circ\). The lowest optimum tilt angle is 52.93\(^\circ\) occurred at August and the highest optimum tilt angle is 57.16\(^\circ\) occurred at November. The optimum tilt angle of solar collector for all months are as follows. In January, February, March, April, May, June, July, August, September, October, November and December are 53.83\(^\circ\), 55.12\(^\circ\), 53.93\(^\circ\), 53.44\(^\circ\), 54.39\(^\circ\), 53.44\(^\circ\), 53.00\(^\circ\), 52.93\(^\circ\), 54.70\(^\circ\), 57.05\(^\circ\), 57.16\(^\circ\), 54.63\(^\circ\), respectively.
4. Conclusions
Optimization tilt angle of solar collector in Medan city using genetic algorithm has been done by considering the Duffie and Beckman equation for solar energy incident on a tilt surface. The result showed that the tilt angle of solar collector must be changed seasonally. This is affected by the annual solar motion. In January, February, September, October, November, and December the sun was in Southern part of the earth, the solar collector has to be directed to South. Therefore, in March, April, May, June, July, and August the sun was in Northern part of the earth, the solar collector has to be directed to north.

References
[1] Ehsanul K, Pawan K, Sandeep K, Adedeji A.A, and Ki-Hyun Kim 2018 Renewable and Sustainable Energy Reviews 82 (894-900)
[2] Sampaio PGV and González MOA 2017 Renewable and Sustainable Energy Reviews 74 (590–601)
[3] M. A. Al-Tameemi and V. V. Chukin 2016 Journal of Atmospheric and Solar-Terrestrial Physics 142 (55-59)
[4] Balaka R, Rachman A, Jaya LDM, 2013. Mitigating climate change through the development of clean renewable energy in Southeast Sulawesi, a developing region in Indonesia, International Journal of Energy, Information and Communications, 4, 4
[5] A. Rachman, “Optimalisasi Teknologi Energi Surya Berbasis Penyesuaian Posisi Panel Bulan di Sulawesi Tenggara,” J. Teknol. Univ. Muhammadiyah Jakarta, vol. 8, no. 1, pp. 1–8, 2016
[6] Ekadewi A.H, Djatmiko I and Prabowo 2013 Energy Procedia 32 (166-175)
[7] A.Messac, Optimization in Practice with MATLAB®: For Engineering Students and Professionals. Cambridge University Press, 2015.
[8] P.Talebizadeh, M. A. Mehrabian, and M. Abdolzadeh, “Prediction of the optimum slope and surface azimuth angles using the Genetic Algorithm,” Energy Build., vol. 43, no. 11, pp. 2998–3005, 2011.
[9] Ambarita H, Ronowikarto A D, Siregar R E T and Setyawan E Y 2018 Journal of Physics: Conference Series 978 012096
[10] Ambarita H, Siregar R E T, Ronowikarto A D and Setyawan E Y 2018 Journal of Physics: Conference Series 978 012097
[11] Tambunan D R S, Sibagariang Y P, Ambarita H, Napitupulu F H and Kawai H 2018 Journal of Physics: Conference Series 978 012099
[12] Ambarita H 2018 IOP Conference Series: Materials Science and Engineering 309 012005
[13] Sitepu T, Sembiring J and Ambarita H 2008 IOP Conference Series: Materials Science and Engineering 309 012007
[14] Ambarita H 2008 IOP Conference Series: Materials Science and Engineering 308 012028
[15] Ambarita H 2017 ARPN Journal of Engineering and Applied Sciences 12(19) 5357-5365
[16] Ambarita H and Sitepu T 2017 IOP Conference Series: Materials Science and Engineering 237 012014
[17] Sitepu T, Gunawan S, Nasution D M, Ambarita H, Siregar R E T and Ronowikarto A D 2017 IOP Conference Series: Materials Science and Engineering 180 012032
[18] Dina S F, Ambarita H, Napitupulu F H and Kawai H 2015 Case Studies in Thermal Engineering 5 32 – 40
[19] Ambarita H 2017 Journal of Physics: Conference Series 801 012093
[20] Siagian P, Setyawan E Y, Gultom T, Napitupulu F H and Ambarita H 2017 IOP Conference Series: Materials Science and Engineering 237 012037
[21] Goldberg D E, Genetic Algorithm, Pearson Education, 2006
[22] Duffie J A, Beckman W A, and Worek W M, Solar Engineering of Thermal Processes, 4nd ed., vol. 116. 2003.