OPTIMAL DESIGN OF A SOLAR PHOTOVOLTAIC TRACKING INTERGRATED SYSTEM

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ABSTRACT

The net increase of global energy demand based on active economic development allow sustainable globalization growth and healthy fiscal condition. However, a significant increase to the existing high carbon emission in the atmosphere due to fossil fuel energy for manufacturing, production and transportation process could foresee a bad environmental issue soon if no drastic approach is discussed and taken. Renewable energy especially solar energy can play a major role to reduce the dependency on fossil fuel energy in order to permit the continuity of power generation with zero carbon emission thus mitigate above mentioned concern. Solar panel system with solar tracker allow almost 30 % increase in terms of energy generation efficiency comparing to conventional solar panel system (Adarsh, Anand, & Singla, 2015). However, the capital investment on solar panel system especially with tracking device is not cheap and solar panel system efficiencies varies upon multiple technical specifications and environment factors. This study was conducted by extracted the location data including location longitude and latitude, energy load demand, surface reflectance factor, optical depth factor and sky diffuse factor. Next the technical utilized were extracted including the solar panel efficiency, inverter efficiency and battery charging and discharging efficiency. Then the model of process flow mechanism was established to be implemented in General Algebraic Modelling System (GAMS) optimization software. Based on the modeling implemented in GAMS, in this study for 30 houses demand, the fixed tilt angle system was optimized at 0 degree with the area of 476 m2 for the total cost of 167 864 USD. This model resulted 51% more power generated with 53% more total cost needed for dual axis tracker system model compared with fixed tilt angle system of the same load and location.

ABSTRAK

Pertambahan permintaan tenaga global berdasarkan perkembangan ekonomi yang aktif membolehkan pertumbuhan globalisasi yang mampan dan keadaan fiskal yang sihat. Walau bagaimanapun, peningkatan yang ketara kepada pelepasan karbon tinggi yang ada di atmosfera disebabkan oleh tenaga bahan api fosil untuk proses pembuatan, pengeluaran dan pengangkutan dapat menyebabkan isu alam sekitar yang tidak baik pada masa hadapan jika tiada pendekatan drastik dibincangkan dan diambil. Tenaga yang boleh diperbaharui terutamanya tenaga solar boleh memainkan peranan utama untuk mengurangkan pergantungan kepada tenaga bahan api fosil untuk membolehkan kesinambungan penjanaan kuasa dengan pelepasan karbon sifar bagi mengatasi isu yang disebutkan di atas. Sistem panel suria dengan jejak suria membolehkan peningkatan hampir 30% dari segi kecekapan penjanaan tenaga berbanding sistem panel solar konvensional (Adarsh, Anand, & Singla, 2015). Walau bagaimanapun, pelaburan modal pada sistem panel suria terutamanya dengan peranti penjejakan tidak murah dan kecekapan sistem panel solar berbeza-beza mengikut spesifikasi teknikal yang banyak dan faktor persekitaran. Kajian ini dijalankan dengan mengutip data lokasi termasuk longitud dan latitud lokasi, permintaan beban tenaga, faktor pemantulan permukaan, faktor kedalaman optik dan faktor meresap langit. Seterusnya penggunaan teknikal telah diekstrak termasuk kecekapan panel solar, kecekapan inverter dan pengecasan bateri serta kecekapan pengeluaran cas. Kemudian model mekanisme aliran proses ditubuhkan untuk dilaksanakan dalam perisian pengoptimuman Sistem Pemodelan Aljabar Umum (GAMS). Berdasarkan pemodelan yang dilaksanakan di GAMS, dalam kajian ini untuk 30 permintaan beban rumah, sistem sudut kecondongan tetap dioptimumkan pada 0 darjah dengan luas 476 m2 untuk jumlah kos 167 864 USD. 51% lebih banyak kuasa yang dihasilkan dengan 53% lebih banyak kos yang diperlukan untuk model sistem jejakan paksi ganda berbanding dengan sistem sudut kecondongan tetap yang sama dengan beban dan lokasi.

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LIST OF ABBREVIATIONS

CdTe	-	Cadmium Telluride
CPV	-	Concentrating Photovoltaic
HSAT	-	Horizontal Single Axis Tracker
GAMS	-	General Algebraic Modeling System
NASA	-	National Aeronautics and Space Administration
NEM	-	Net Energy Metering
PV	-	Photovoltaic
VSAT	-	Vertical Single Axis Tracker

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

The growth of global economy situation allows healthy trading activities between countries, secure financial strength of populations and increase government income hence allow government to improve public services and infrastructure. However, global economy directly correlated with global energy demand. Generally, global economy growth is directly proportional to global energy demand. Energy demand based on electricity and heat, industry, transport, buildings are some of the major division of sectors which contributes to the highest emission of carbon dioxide (CO_2). Based on International Energy Agency (IEA, 2019) in Figure 1.1, as of 2016 from fuel combustion alone, 32.31 $GtCO_2$ had been emitted globally. While this result was predominantly similar to 2015 levels, comparing with the early 70s however, the emissions had doubled and increased by around 40% since 2000. Asia was the dominant source of emissions with 17.4 $GtCO_2$ for 2016 as China accounted for 52% (9.10 $GtCO_2$) of the emissions followed by India for 12% (2.08 $GtCO_2$). In 2016, the largest source of emissions are electricity and heat generation sectors with 42% (13.41 $GtCO_2$) accounted from the global total CO_2 emission. Other sectors such as transport and industries marked at second with 24% (7.87 $GtCO_2$) and third with 19% (6.11 $GtCO_2$) respectively.

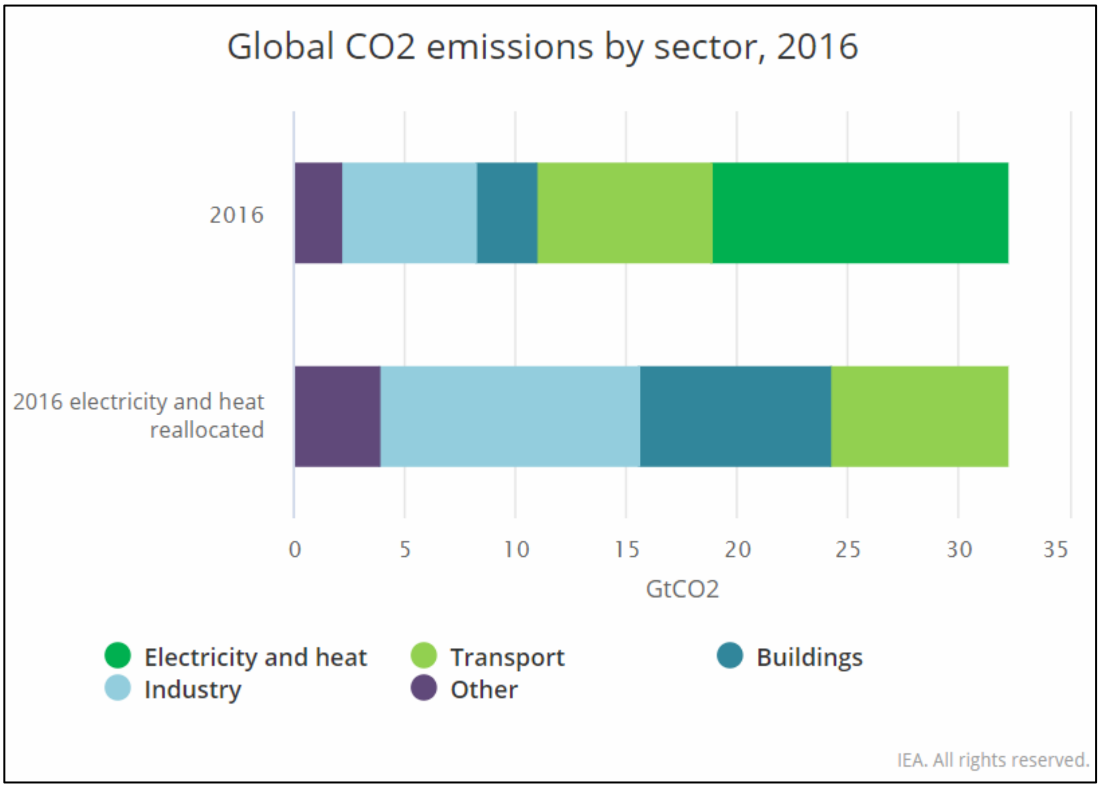

Figure 1.1 CO2 emissions by sectors (IEA, 2019).

The increased concentration of CO_2 in the atmosphere results in temperature rise. The increase in the temperature is the major cause for all other changes in earth's climate. These effects are having several physical impacts such as sea level rise, increased variability in weather patterns and extreme weather events. Based in Figure 1.2 from Met Office Hadley Centre observations datasets, over the last few decades, a steep increase in global temperature level can be observe clearly (Morice, Kennedy, Rayner, & Jones, 2012). As of 2017, current average temperature was approximately 0.8 °C higher than the baseline of 1961-1990. While comparing to 1850, the average temperature was 0.4 °C lower than the baseline of 1961-1990. Hence the comparison between 2017 and 1850 therefore resulted to an approximately 1.2 °C increment level which indicated that we already exceeded one degree.

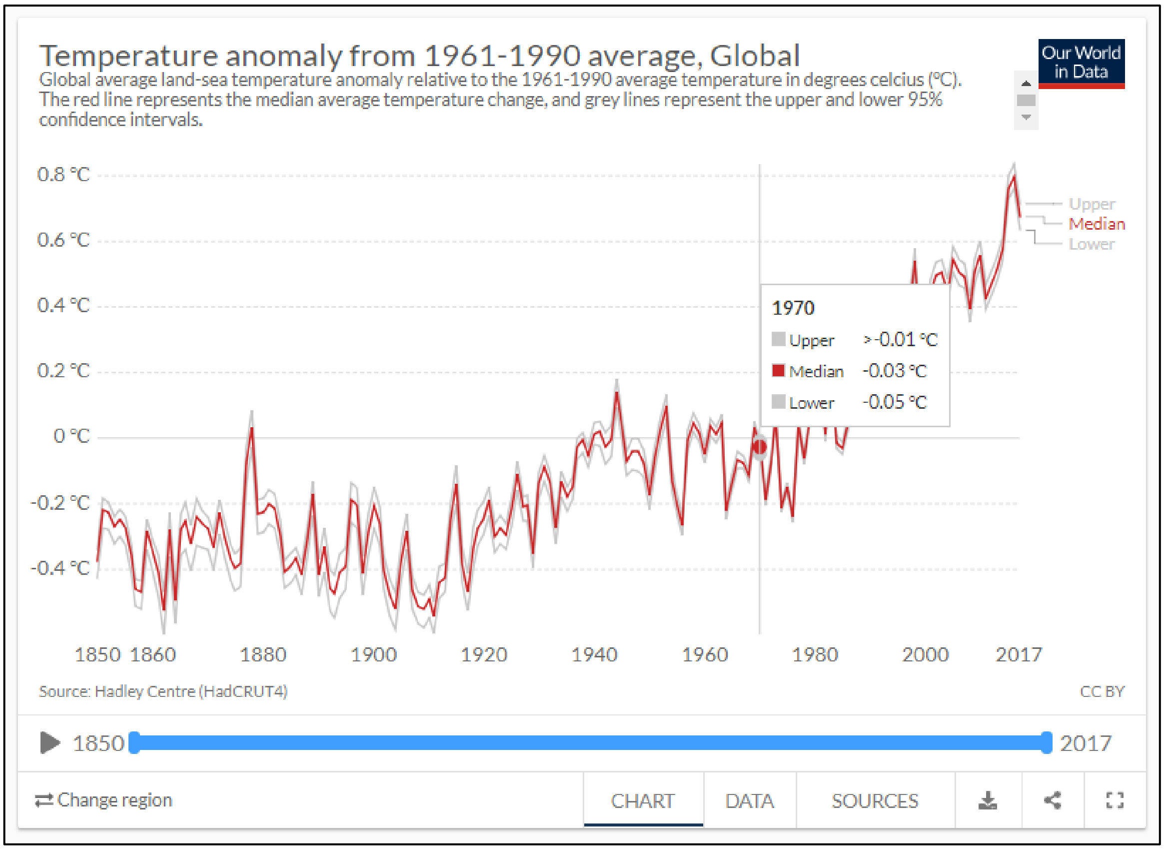

Figure 1.2 Temperature anomaly from 1850-2017 (Morice et al., 2012).

Interesting to note that The Paris Agreement (2015) long-term goal is to remain the increment in global average temperature to well below 2 °C above pre-industrial levels and to limit the increase to 1.5 °C. The best way to mitigate carbon emissions while maintaining economic growth is to apply decoupling process between economic growth and carbon emissions. This simply implies that deep carbon emission reductions are possible with little or no effect on economic growth (Deutch, 2017). Raw material procurement, manufacturing procedure, production process, distribution stage, product disposal and all other activities which contributed to the growth of economy will inevitably contributed to carbon emissions. The current conventional fuel for global energy and electricity economy sector is fossil fuel. Globally noted that renewable energy is one of the most effective mitigation replacement technology in order to allow energy production as per demand by industry with zero carbon emission as per environmental concern today or permit this decoupling idea.

Countries such as Iceland, Sweden and Costa Rica are the top three countries which utilize renewable energy more than non-renewable while proven to be able to sustain their economy. In other word, these three countries able to implement decoupling process. There are many forms of renewable energy such as wind energy, hydroelectric power, solar energy, biomass energy, geothermal energy and tidal energy. Each renewable energy has their own advantages and disadvantages as well as global utilization preference. For instance, the growth of solar panel system installed globally shown a tremendous positive trend annually as per Figure 1.3. As of 2013, based on IEA report, the total installed panel achieved 139 GW capacity (Reve, 2014). These trend generally due to solar energy technology affordability as panel, battery and cell are constantly being developed to produce greater efficiency with a cheaper price while the flexibility to allow small scale or larger scale utilization.

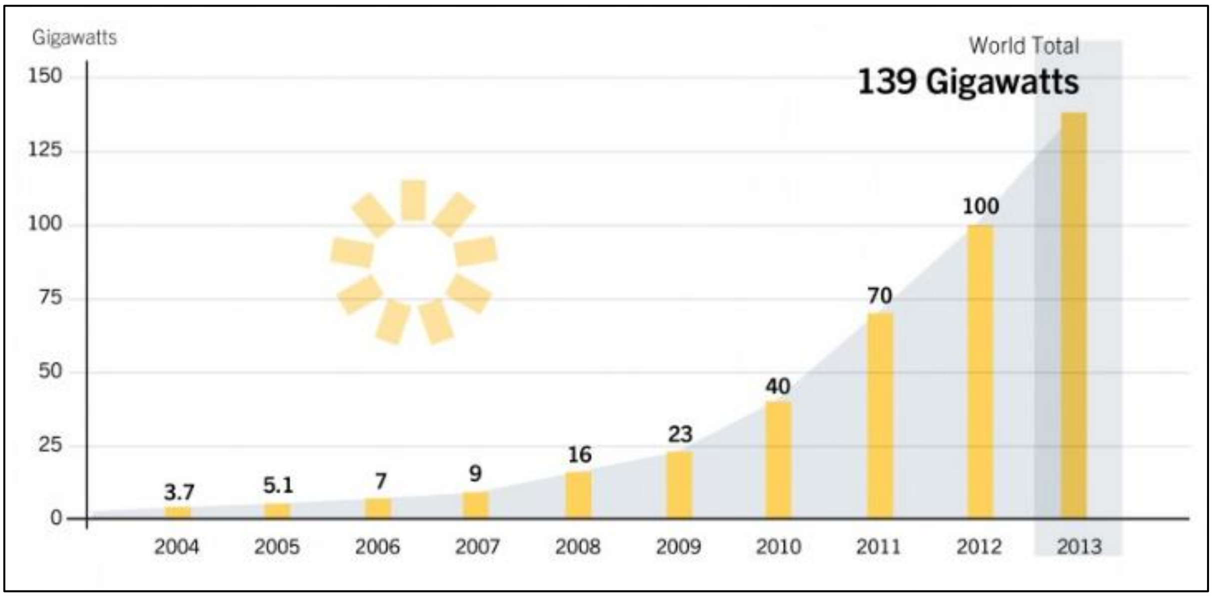

Figure 1.3 Global installed solar panel system capacity (Reve, 2014).

In Malaysia, the Ministry of Energy, Science, Technology, Environment and Climate Change, Minister Yeo Bee Yin had adopted the Net Energy Metering (NEM) scheme in the objective to increase Malaysia's renewable energy mix from 2% to 20% by 2030. Following the trend of global solar panel technology demand and local interest in renewable energy, this study will hence provide an aid of research data on solar system optimization in terms of cost for any location given the technical and environmental data are known as the capital investment for such larger scale target is not cheap.

1.2 Problem Statement

Solar photovoltaic panels are widely used to harvest solar energy due to impressive longevity reliability, low maintenance cost and flexible to apply for small low budget scale or large high budget scale installation. However, since solar panel to be installed in a certain location depend on the maximum incident angle on that location as well as longitude and latitude, hence it is difficult to decide which solar panel system type is better than another with reference to another performance result at different places. Solar tracking system although increase the performance of solar system, solar tracking system consume energy for operation other than increase the capital and operating expenditure of the existing high initial capital cost of a standard conventional solar panel installation project.

In Malaysia particularly, electricity is much cheaper thus makes the interest to switch to renewable energy is not as attractive as other countries. Complex solar optimization model case by understanding and consider all environmental data and cost into account per technical specification utilized had not been investigated in any research in Malaysia. Lack of detailed optimization model design results in oversized installation system implemented which ultimately cost more than it should.

1.3 Objective

The objective of this study are as follows:

1. To develop mathematical model using General Algebraic Modeling System (GAMS) which allow optimization of solar panel system design suiting

location data between standard conventional solar panel installation specification and solar panel installation with solar tracking system specification.

2. To perform cost scenario analysis on different variable input between standard conventional solar panel installation specification and solar panel installation with solar tracking system specification.

1.4 Scope of Study

The scope of study comprises:

1. Performing state of the art analysis on existing and new solar panel system.

2. Collecting secondary data which includes technical, location and cost input data.

3. Developing superstructure for the model.

4. Defining mathematical progression for the model.

5. Performing General Algebraic Modeling System (GAMS) programming and optimization.

6. Performing multiple scenario analysis to evaluate cost optimization in terms of capital and operational cost.

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