Adaptive control of solar tracking system

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Abstract: In this study, an adaptive controller of a solar tracking system is designed and its performance is evaluated through computer simulation. To achieve this goal, two tracker systems based on open- and closed-loop control strategies are studied. The instantaneous and total errors that represent the differences between the tilt and rotation angles of both the open- and closed-loop systems are analysed. An adaptive controller that regulates the electric signals to the motors is designed. Owing to uncertainty in the sun position data, the performance of solar tracker suffers degradation. Towards this end, sun position data are analysed to extract the error sources. The designed control system objective is to keep the tracker perpendicular to sunlight at all times during the day and eliminate modelling errors such as sun position data deviations, friction and environmental changes. System performance is verified through computer simulation where the controller corrected for modelling errors and date changes from the date used for algorithm design. More specifically, in the first case the square error reduces from 15.43 to 12.18 degrees2 for azimuth angle and from 39.05 to 19.09 degrees2 for altitude, whereas in the latter case the square error reduces from 236.92 to 105.90 degrees2 for azimuth angle and from 402.82 to 40.40 degrees2 for altitude.

1 Introduction

Unlike some other countries in the Middle East, Jordan is a non-oil producing country and is nearly fully dependent on imported oil and natural gases from neighbouring Arab countries. Its current imports of about 100 000 barrels of crude oil per day are placing the country under extreme economic pressures, especially with the increasing unit price of oil in the international market. In recent years, concerns about energy consumption in Jordan and its adverse impact on the economy and environment have been growing [1]. In addition to energy use, the associated greenhouse gas emissions and their potential effects on the global climate change are nowadays a worldwide concern. Jordan’s annual CO2 emissions were estimated in 2004 to be 16.70 × 106 Ton. Although this constitutes less than 0.1% of the world’s annual CO2 emissions, its intensity is considerably higher: about four times that of most Western European countries, and almost similar to those of oil producing Arab countries as indicated in Fig. 1 [2].

Solar tracking has become a vital issue in the last two decades because of its importance in increasing efficiency of the solar collectors and the availability of hardware that enables tracking. A parabolic solar collector was designed and built in Jordan with a water pipe located exactly on the focus [3]. In order for all the incident solar radiation to be concentrated on the focus or water pipe, the collector has to be perpendicular to the sunlight. Towards this end, a feedback controller was designed and implemented with the objective of precise solar tracking in order to make the water through the pipe attain the maximum heating from solar energy. The developed solar system performed well.

The low insulation levels of solar radiation in Northern European regions motivate solar collectors to be equipped with a tracking mechanism for an increased yield. In [4], the authors describe the performance of photovoltaic (PV) modules with daily two-positional tracking. The symmetrical and asymmetrical positions about the north–south axis are analysed, corresponding to the positions of sun in the morning and in the afternoon. Results indicate that the seasonal energy yield is increased by 10–20% over the yield from a fixed south-facing collector tilted at an optimal angle.

Advanced solar tracking tools have been implemented very recently. The sun tracking system of a solar dish based on computer image processing of a bar shadow was investigated in [5]. This is done by using a camera to obtain the optimised picture of a bar shadow on a screen by solar dish displacements. This system is independent respect to geographical location of the solar dish and periodical alignments such as daily or monthly regulations. Furthermore, the operation of the system is independent respect to the initial configuration and the start time situation.

In [6], the most general form of sun-tracking formula that embraces all the possible on-axis tracking methods was presented. The general sun-tracking formula not only can provide a general mathematical solution, but more significantly, it can improve the sun-tracking accuracy by tackling the installation error of the solar collector. A new PV design, called ‘one axis three position sun tracking PV module’, with low concentration ratio reflector was