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EFFECTIVE POWER GENERATION SYSTEM FOR DAY AND NIGHT USING SOLAR POWER WITH TRACKING AND MOLTEN SALT TECHNIQUES

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Abstract

Solar energy is rapidly gaining popularity as an important means of expanding renewable energy resources. The main drawback of solar power generation is, it is limited to day light. To avoid such limitations this paper presents the concept of utilizing the solar power for day and night with effective solar tracking system for day time and molten salt technique for night time. Solar tracking allows more energy to be produced because the solar array is able to remain aligned to the sun. The solar tracking can be designed using microcontroller. Molten salts can store the sun's heat during the day and provide power at night.

Key Words: Solar Tracking, Molten Salt, Renewable Energy

I. Introduction

Renewable energy solutions are becoming increasingly popular. Photovoltaic (solar) systems are but one example. Maximizing power output from a solar system is desirable to increase efficiency. In order to maximize power output from the solar panels, one needs to keep the panels aligned with the sun. As such, a means of tracking the sun is required. This is a far more cost effective solution than purchasing additional solar panels. It has been estimated that the yield from solar panels can be increased by 21 percent by utilizing a single axis tracking system instead of a stationary array [1].

One drawback about the solar energy is, It can be utilized in day time only. To overcome the drawback of day time limitation, this paper introduce a new concept of utilizing the solar power in day time using solar cells and night time using molten salt.

This paper begins with presenting a review of the sun-tracking technologies, the paper continues with specific design methodologies pertaining to photocells, stepper motors and drivers, microcontroller selection, voltage regulation, physical construction, and a software/system operation explanation. Also includes the night time power generation using molten salt technique. The paper concludes with a discussion, expected results and future work.

II. Review of Sun-Tracker & Molten Salt Technology

There are a number of works proposed by many researchers to track the sun. Kalogirou and Alata et al. suggested [2,3] a tracking system which can be used with single-axis solar concentrating systems, Roth et al. and Bakos [4,5] constructed and tested two axis tracking system. Different types of one-axis tracking systems have been applied in the literature [6–8]. Tomson [6] described mainly the performance of PV modules with daily two-position in the morning and in the afternoon. Results indicated that the seasonal energy yield was increased by 10-20% over the yield from a fixed south facing collector tilted at an optimal angle.

Huang and Sun [7] has designed the solar tracking system called ‘‘one axis three position sun tracking PV module” with low concentration ratio reflector. The one-axis tracking mechanism adjusted the PV position only at three fixed angles. These are the morning, the noon and the afternoon. An experiment performed in the present study indicated that economic analysis showed that the price reduction was between 20% and 30% for the various market prices of flat plate PV modules. Abu-Khadera et al. [9] investigated the effects of multiaxes sun-tracking systems on the electrical generation of a flat photovoltaic system (FPVS) which was carried out to evaluate its performance under Jordanian climate. Multi-axes (N–S, E–W, vertical) electromechanical sun-tracking system was designed and constructed. The measured variables were compared with that at fixed axis. It was found that there was an overall increase of about 30–45% in the output power for the north–south axes (N–S)-tracking system compared to the fixed PV system.

Also, it was found that the N–S axes sun tracking was the optimum. Bakos [5] performed to investigate the effect of using a continuous operation wo-axes tracking on the solar energy collected. The collected energy was measured and compared with that on a fixed surface tilted at 41 towards the south. The results showed that the measured collected solar energy on the moving surface was considerably larger (up to 46.46%) compared with the fixed surface.

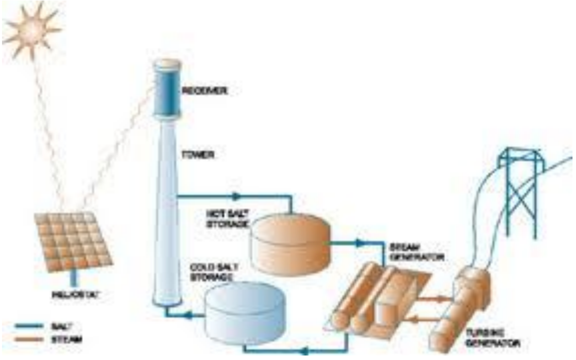
Abdallah [10] implemented four electromechanical sun-tracking systems, two axes, one axis vertical, one axis east–west and one axis north–south, were designed and constructed for the purpose of investigating the effect of tracking on the current, the voltage and the power, according to the different loads. The results indicated that increases of electrical power gains up to 43.87% for the two axes, 37.53% for the east–west, 34.43% for the vertical and 15.69% for the north–south tracking, as compared with the fixed surface inclined 32 to the south in Amman.

There are also many different controllers such as PC, PLC, PLA, microcontroller and electro-optically to implement the control techniques [11– 16]. In addition to this Georgiev et al. [17] expressed that modern measuring and registering system for actual data more easily than conventional systems [17]. When the literatures are analyzed, the parameters such as the installation, the mechanism, the cost, the efficiency, the design and the maintenance have been given as important features depend on tracking methods as given in Table 1.

Parameters	Fixed	One Axis	Two Axis	Developed System
Installation	Easy	Easy	Difficult	Easy
Mechanism	No Mechanism	Simple	Complicated	Simple
Cost	Cheap	Moderate	Expensive	Moderate
Efficiency	Reference efficiency	10-35%	25-45%	10-45%
Design	Simple	Moderate	Complicated	Simple
Maintenance	Less	Moderate	More	Less

Table 1: Comparison of Solar Systems.

The proposed solar system with molten salt is shown in fig.



The salts will soon help the facility light up the night literally. Because most salts only melt at high temperatures (table salt, for example, melts at around 1472 degrees Fahrenheit, or 800 degrees Celsius) and do not turn to vapor until they get considerably hotter they can be used to store a lot of the sun's energy as heat. Simply use the sunlight to heat up the salts and put those molten salts in proximity to water via a heat exchanger. Hot steam can then be made to turn turbines without losing too much of the original absorbed solar energy.

The salts a mixture of sodium and potassium nitrate, otherwise used as fertilizers allow enough of the sun's heat to be stored that the power plant can pump out electricity for nearly eight hours after the sun starts to set. "It's enough for 7.5 hours to produce energy with full capacity of 50 megawatts," says Sven Moormann, a spokesman for Solar Millennium, AG, the German solar company that developed the Andasol plant. "The hours of production are nearly double [those of a solar-thermal] power plant without storage and we have the possibility to plan our electricity production."

To allow the salts to get hotter, power towers with vast fields of mirrors that concentrate sunlight onto a central tower. Because of the centralized design such a structure can operate at much higher temperatures up to 1,000 degrees F (535 degrees C) and use molten salts directly as the fluid transferring heat in the power plant.

III. Materials and Methods For Solar Tracker

The solar elevation tracker is a closed loop control system that covers both fields of electronics and mechanical engineering. This system is used to position solar panels to positions of the sun so as to achieve higher efficiency of power generation. The components of the electronic system consist of a Microcontroller logic circuitry, a Comparator, a DC motor, a relay, cadmium Sulphide photoconductive cells (photo sensors), a Transformer. These components are grouped into the following units and illustrated in the block diagram below in figure 1:

1. Power Unit.
2. Comparator Unit.
3. Control Unit.
4. Relay Unit.

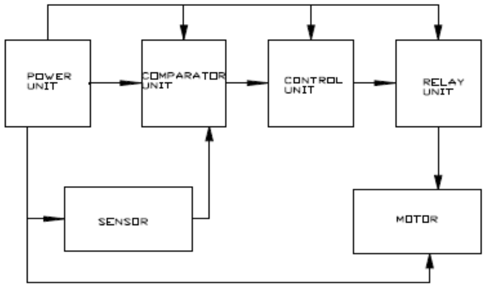


Fig. 1 Block diagram of the system

Power unit:

This consists of a 220-12V 500mA Step down Transformer with a rectified output of 12V. This rectified output is smoothened by a 2200µF capacitor, the 7805 voltage regulator converts the 12V rectified filtered voltage to a voltage level of +5V which is used by the AT89S51 microcontroller and the comparator (LM324). Circuit is presented in figure 2.

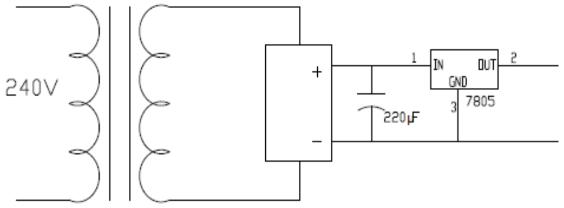


Fig. 2: Power unit circuit

Comparator unit:

This is achieved by using the operational amplifier LM324. This consists of four independent, high gain, internally compensated operational amplifiers which were designed specifically to operate from a single power supply over a wide range of voltages. Operation from split power supplies is also possible and low power supply current drain is independent of the magnitude of the power supply voltage.

Light sensor:

Light sensors are among the common sensor type. The simplest optical sensor is the photo resistor which may be a cadmium sulphide (CdS) type or a Gallium Arsenide (GaAs) type. The next step in complexity is the photodiode followed by the phototransistor. The sun tracker uses cadmium sulphide (CdS) photocell for sensing. This is the least expensive and least complex type of light sensor. The LDR is a resistor whose resistance decreases with increasing light intensity. It can also be referenced to as a photo conductor. A photo resistor is made of high resistance semiconductor. If light falling on the device is of high enough frequency, photons absorbed by the semiconductor give bound electrons enough energy to jump to the conduction band. The resulting free electron and its hole partner conducts electricity, thereby lowering resistance. The reverse is the case when darkness falls on the LDR, for this will increase its resistance. This characteristic of the LDR is used to vary the input voltage into the comparator as the sun moves over it.

Creating varying voltage using an LDR:

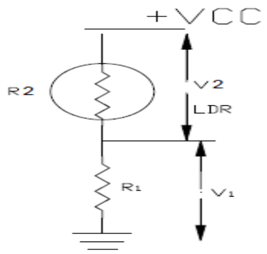


Fig. 3: How LDRs are connected in the circuit

The LDR is connected in series with a resistor (Fig. 3); a voltage divider is thus formed, which will split the voltage Vcc into two. As darkness sets in, the resistance of the LDR increases. Following the common formulae V=IR. If R increases when I is constant, then V is increased. Therefore V2 increases while V1 reduces obeying the Kirchoff voltage law which state

Comparator circuit:

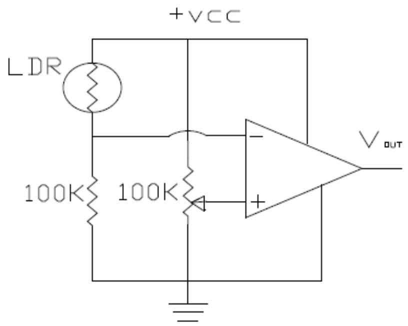


Fig. 4: The comparator circuit.

Initially the voltage at the non inverting input is set lower than that of the inverting input. As darkness increases, the voltage at the inverting input begins to drop until it gets below that of the non-inverting input. At this point, the output of the comparator is changed from low to high. We achieve this with the circuit in Fig. 4.

How this is used to accomplish the tracking:

Three of the comparators are used in the format as specified above. They are used for finding the rays of the sun; the third is placed behind the platform as shown below

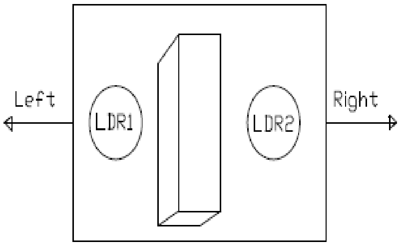


Fig. 5: Diagram of the LDRs on the platform

Both LDR, as shown in figure 5, are placed on a flat platform, a barrier demarcates them from each other. The arrows signify the direction of rotation of the solar finder. If the sun is at normal (i.e. when both LDR sees light), the output of the comparator is expected to be low, as a result the control unit which would be discussed later would not perform any operation. If the barrier cast its shadow on LDR1 as the sun moves to the right, the system would rotate to the right and will continue to do so until both LDR sees light again. When the sun sets both LDR will see darkness and the system will not rotate at all, it will remain in that position till the next day.

When the sun rises, the last LDR placed underneath the platform senses the sun's light which activates the rotation of the system back to the left (Eastward), this movement will continue until both LDR on top of the platform senses light again.

Control unit:

This consists of a microcontroller which functions with a crystal oscillator, reset capacitor and the enable pin (Pin 31) connected to Vcc as shown in figure 6.

Since the project's focus is on embedded software control, the microcontroller is the heart of the system. The microcontroller selected for the project had to be able to convert the analog photocell voltage into digital values and also provide output channels for motor rotation. The AT89S51 was selected because it meets these requirements. A 33MHz was used in conjunction with the AT89S51 to provide the necessary clock input. This speed is sufficient with the system.

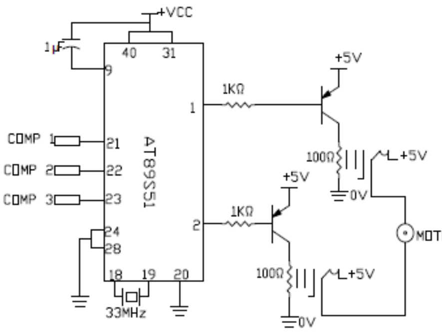


Fig.6. Circuit diagram of the control and relay unit

The solar tracker uses a 12V motor and is powered by two 6V relay. This was done so that the motor speed is reduced, together with the mechanical unit; it ensures that the system moves slowly. This has an advantage in that the system does not overshoot the movement of the sun. Fig. 7 shows a complete circuit diagram of the project.

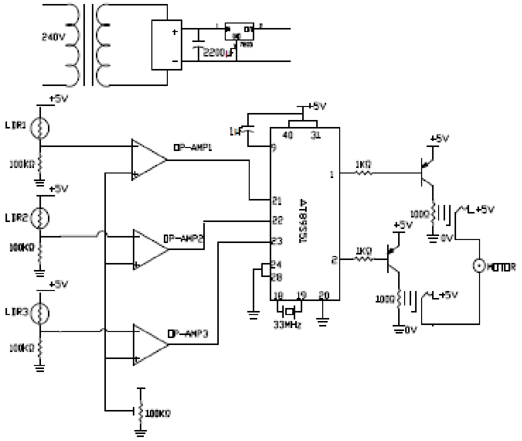


Fig 7 Complete circuit diagram

IV. Methods & Materials for Molten Salt technique:

In a molten-salt solar power tower, liquid salt at 290ºC (554ºF) is pumped from a 'cold' storage tank through the receiver where it is heated to 565ºC (1,049ºF) and then on to a 'hot' tank for storage. When power is needed from the plant, hot salt is pumped to a steam generating system that produces superheated steam for a conventional Rankin cycle turbine/generator system. From the steam generator, the salt is returned to the cold tank where it is stored and eventually reheated in the receiver. Figure 8 is a schematic diagram of the primary flow paths in a molten-salt solar power plant. Determining the optimum storage size to meet power-dispatch requirements is an important part of the system design process. Storage tanks can be designed with sufficient capacity to power a turbine at full output for up to 13 hours.

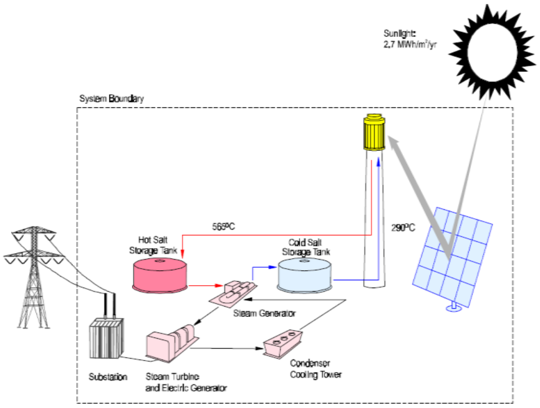


Figure 8. Molten-salt power tower system schematic

The heliostat field that surrounds the tower is laid out to optimize the annual performance of the plant. The field and the receiver are also sized depending on the needs of the utility. In a typical installation, solar energy collection occurs at a rate that exceeds the maximum required to provide steam to the turbine. Consequently, the thermal storage system can be *charged* at the same time that the plant is producing power at full capacity. The ratio of the thermal power Sunlight provided by the collector system (the heliostat field and receiver) to the peak thermal power required by the turbine generator is called the solar multiple. With a solar multiple of approximately 2.7, a molten-salt power tower located

in the California Mojave desert can be designed for an annual capacity factor of about 65%. (Based on simulations at Sandia National Laboratories with the SOLERGY computer code.) Consequently, a power tower could potentially operate for 65% of the year without the need for a back-up fuel source. Without energy storage, solar technologies are limited to annual capacity factors near 25%.

V. System Benefits -Energy Storage

The availability of an inexpensive and efficient energy storage system may give power towers a competitive advantage. Table provides a comparison of the predicted cost, performance, and lifetime of solar-energy storage technologies for hypothetical 200 MW plants.

	Installed cost of energy storage for a 200 MW plant ($/kWhr$_e$)	Lifetime of storage system (years)	Round-trip storage efficiency (%)	Maximum operating temperature (°C/°F)
Molten-Salt Power Tower	30	30	99	567/1,053
Synthetic-Oil Parabolic Trough	200	30	95	390/734
Battery Storage Grid Connected	500 to 800	5 to 10	76	N/A

VI. A Prototype Solar Tracker:

The final stage involved coupling the circuitry to the motor and mounting it onto the bracket. The final product is seen complete in Fig. 9. It has a Solarex 9W solar array made of polycrystalline silicon mounted on the flanges, which was borrowed from the tech officers. Quite simply having two test subjects carried out testing. The first scenario involved removing the panel from the tracker and laying it in a flat orientation. The output was connected to a load that would dissipate 9W that would match the panel's rating. 9W at 12V corresponds to a current of 0.75A, so by Ohm's law; a load resistance was calculated as being 16Ω. A 15Ω 50W resistor was the closest value found and was connected to the panel. The tracking device still requires power, but a 12V battery that is connected in a charging arrangement with the solar panel supplies it. The voltage across and current through the load was monitored using two separate multimeters, and was recorded every half-hour on a clear day into an Excel spreadsheet. The readings were taken on a span of days that possessed similar conditions including no cloud cover. The readings are shown below in a graph generated by Excel in Fig. 10.

Fig. 9 A prototype solar tracker

VII. Results and Discussion:

As for now the solar tracking system using microcontroller was designed and tested. The combination of solar tracking with molten salt will be tested in future.

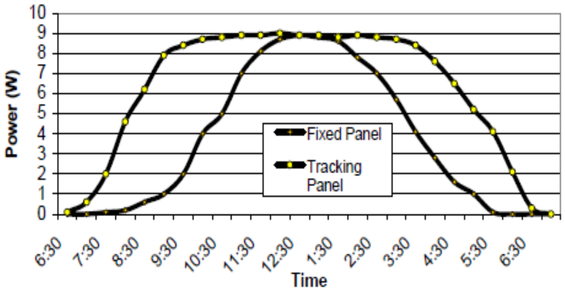


Fig. 10 Experimental results of power increase for tracked panel

A solar tracker was proposed, designed and constructed. The final design was successful, in that it achieved an overall power collection efficiency increase from only 39% for a fixed panel to over 70% for the same panel on the tracking device. In terms of real value, this means that the overall cost of a system can be reduced significantly, considering that much more power can be supplied by the solar array coupled to a solar tracking device. By extracting more power from the same solar panel, the cost per watt is decreased, thereby rendering solar power much more cost-effective than previously achieved using fixed solar panels.

VIII. Conclusion

A solar tracker is designed employing the new principle of using small solar cells to function as self-adjusting light sensors, providing a variable indication of their relative angle to the sun by detecting their voltage output. By using this method, the solar tracker was successful in maintaining a solar array at a sufficiently perpendicular angle to the sun. The power increase gained over a fixed horizontal array was in excess of 30%.

Part of the proposed system was designed and tested. The remaining part of combining both solar tracker with molten salt will be done in future.

IX.Future Work

For Tracking:

1. Increase the sensitivity and accuracy of tracking by using a different light sensor. A phototransistor with an amplification circuit would provide improved resolution and better tracking accuracy/precision.
2.Utilize a dual-axis design versus a single-axis to increase tracking accuracy.

For Molten salt:

1.The system have to be tested by combining solar cells with tracking system.
2. The efficiency of utilization may be improved from 65% to higher trying with many combinations of salts.

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