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An Advanced and Efficient Sun Tracking System based on a Novel Algorithm for Maximum Electrical Power Generation on Solar Array

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Introduction

- primary energy source for electrical power generation is mainly oil and natural gas.
- Oil deposits gradually diminish by continuous pumping and the growing demand of energy as well as the cost per energy unit is increasing rapidly.
- environmental pollution after oil burning and temperature increase of atmosphere are two great factors affecting the ecosystem, our lives and whole Earth.

The solution

- Renewable energy sources, or Green Energy sources, like sun, wind, geothermal and tidal waves on sea will be the solution .
- All these hopefully declare the survival for people in a healthy and safer environment.

Photovoltaic (PV) panels and their application techniques

Photovoltaic panels.

- PV panels convert solar energy to electric.
- They are made with PV cells, based mainly on silicon (Si) semiconductor and connected in series and parallel.
- There are the following types of PV panels in the market:

✓ Monocrystalline with efficiency from about 13.5% to 20%

✓ Multicrystalline (Polycrystalline) with (electrical) efficiency from about 12.5% to 17.5%

✓ Thin film panels with efficiency from about 6% to 8%. With alloys of Si and C (carbon) or Ge (germanium) their efficiency can reach to 13%.

PV properties relative to incident sunlight

- Their efficiency gets maximum when their orientation is towards sun (incident angle close to 0^0).
- For incident angles up to 8^0 power loss relative to 0^0 is 1% and increases to about 10% at angles close to 25^0.
- Power degradation, averaged on a day, can reach 35% to 40% due to misalignment with sun.

PV application techniques

There are two ways of implementing a PV field plant, relative to its orientation to the sun.

1. *Fixed mount systems*

- PV panels form a group and are placed on a fixed base with permanent orientation on a photovoltaic (PV) field area.

Advantages:

- Lower cost, mechanical simplicity and robust construction

Disadvantage:

- Power degradation can reach to 35% - 40% due to misalignment with sun

2. *Solar tracking systems*

These systems have PV panels fixed on a moving surface and track the apparent motion of the sun through a day. Their scope is to increase power efficiency of panels, as the system tends to orient in the direction of sun

There are two types of trackers, depending on the way of motion and consequently on their moving axes. They are one axis and two axes trackers

One axis trackers

- They have one degree of freedom and move the panels from east to west. They don't change the tilt of panels and have an efficiency reaching to 30% more compared to fixed mount installations.

Two axes trackers

- They have two degrees of freedom and move panels on East-West and North-South directions. These trackers, ought to their composite movement, orient panels normal to the sun and have the maximum efficiency (35%-40% more than fixed systems), but are more expensive.

Techniques and algorithms employed for a tracker.

Closed loop technique.

The system tracks the apparent motion of sun continuously and moves PV panels, so minimizing the relative error between sun and panel's position.

Primary disadvantages:

- The orientation loss if a cloudy sky or a cloud remains for a long period over the area. Then the system stops moving, but when the clouds have gone, it needs a period of time to turn its surface normal to the sun and 'lock' the movement with that of sun. This is an important limiting factor of performance.

- The panels start moving from west back to the east during the sun rise period in the morning, with a time delay, depending on topology, design and electro-mechanical parts having an impact at performance.

Open loop technique

It is based on algorithms for computing the direction of the system during the day time, season and for the whole year with the solution of mathematical formulas for earth orbit around the sun.

Disadvantage:

- It's not possible to correct its tracking position if parameters, like its geographical coordinates, real time clock or its reference point based on the system itself, are lost or wrong. A GPS is usually applied to the construction to avoid the first malfunctions but a mismatch between sun and PV orientation still could happen.

Composite technique

which combines the above two methods for minimizing the corresponding disadvantages but it still has a problem if a relatively large orientation difference occurs between the predicted and real coordinates of sun.

- For example, suppose the sun is obscured by a cloud for a time period, then the system will be forced to a faulty movement, to reach the calculated position based on open loop technique algorithm and later on, as the sun shines, it has to follow one more (unnecessary) tracking movement to the sun.

An advanced and innovative tracker design

This is a solar tracking system which overcomes the disadvantages of all the above described methods.

It's a composite, autonomous and reliable two axes tracking system. On the way of operation this is based on composite technique as:

- a closed loop technique with advanced topology of photodiodes for sun tracking. System is governed by an optical array of photodiodes, fixed at the PV panel assembly. Data from this array of photodiodes have the largest priority and handle the management and control of tracker, while it's not obscured by clouds.

- an open loop technique, in case of a cloudy weather, capable to compute and predict the sun position.
- an innovative algorithm, independent of geographical coordinates or real time clock, without complicated mathematical equation solutions and a minimum program size on system memory, has been developed for this tracker. This algorithm combines real sun position data and calculated data, to achieve a minimum error estimation of sun position during open loop operation.
- Additionally to all these, the described system detects wind speed and consequently controls panel surface slope, when wind exceeds a predefined limit, then the panels move getting parallel to ground and air pressure is minimized on PV's, avoiding possible damage.

An approach to system technical aspects and procedures

- ***Closed loop operation***

Closed loop operation has the largest priority on system and handles the management and control of tracker during sunny periods. We distinguish between two scenarios:

- *Initial operation*

The following procedures take place in system after it has been oriented to the sun:

- A) It identifies if initial orientation with sun is before noon or after. This is based on advanced firmware and a reference point, with two coordinates, indicating the directions of North – South and zenith point of the place.
- B) It calculates the position (coordinates) of sunrise, for next day morning (second day of operation) and moves to this orientation before sunrise. This is achieved by a computational algorithm, developed for this tracker, with analysis of the data recorded on the day before (first day of operation).

- *Daily operation*

As the tracker follows the sun, a set of data consisting of azimuth, tilt and the time stamp of samples, is recorded. This operational circle repeats for a time interval of the last 15 days and after suitable manipulation of these data, the tracker:

- A) can calculate and predict its position and motion, relative to sun, for any time and day, on overcast sky.
- B) can calculate its position and motion during a day, for at least 15 days to provide the worst-case cloudy sky, e.g. during continuous cloudy sky for a week.
- C) does not need a real-time clock, like the aforementioned commercial systems. The system will always move in the right direction to track the sun.

➢ ***Open loop operation***

The tracker operates on open-loop technique during cloudy sky period, it is self-corrected by comparison the calculated with the real position data, when the clouds remove. The system works with the ‘’daily operation’’ scenario as described above.

- The system has a ‘self learning' algorithm, based on real sampled data, computes (with minimal fault) the correct position for next 15 days, regardless of a cloud presence. The aim is its ability to predict real sun position for a great number of days, expanding it in whole season period and finally for a year period. This is achieved without solving complicated mathematical equations.

Some more applications

- This tracking system could operate in large solar parks with a lot of PV arrays, installed on many trackers. It can be used as the master tracking unit and all the other systems will be passive. They will only have the mechanism of movement, without any electronic units, like microcontroller board, photodiode array, photo amplifiers etc.

The main unit should control and check all the trackers and their orientation. A base station is introduced for this PV park with a computer connected to the master tracking unit to keep data of all the individual tracking systems in the park and will be possible to make statistical curves, daily based, for sunlight, the clouds, the produced energy and many other parameters that are useful in a large PV installation.

- The above described tracker is reliable and accurate, with minimal error on incident angle. Therefore it is appropriate for applications on concentrating PV systems (CPV) and concentrating solar thermal installations.

Conclusions

- This tracker design, with it's innovative concept, gives the chance for developing systems with higher efficiency, more reliable, simpler on operating method and safer. The suggested solar tracking system will have immediate implementation on photovoltaic market and will be competitive for its benefits including its easier initialization when installed.

Thanks a lot