Cloud7

Requirements Specification

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1. Introduction

1.1 Purpose

Photovoltaic solar panels are becoming increasingly used throughout the country; in some places up to 10% of the areas power (and even up to 40% in remote places such as Maui). The problem with solar panels is that cloud cover can dramatically decrease the amount of power produced by these PV arrays within a matter of seconds. With the increasing number of PV arrays being used, power companies need to be able to accurately forecast the cloud coverage and predict the amount of energy that will be produced from these solar panels. Solar forecasting will help power companies prepare and backup enough energy for these concerning times of cloud cover, but will not require the constant backup of of fossil fuel power as is needed currently.

1.2 Scope

Our goal is to create two different long lasting and inexpensive sensors. One that will take sky images and another that will measure on grid solar power generation from residential PV arrays. The sky images will be used to generate a forecast of the clouds and solar insolation, while the on grid sensor will be measuring real-time data. Both these sensors will this data to a central server (via internet or the cellular network network) every 30 seconds. This server will be programmed to create a timelapse of the solar insolation in order to predict where and when solar energy either will or will not be available. These will include what areas will be covered by clouds up to 1 hour in advance. Ideally, Power companies will take this data in order to determine the solar power that will be generated based on their knowledge of the distribution of PV arrays across the power grid. This way power companies will know if they will need to be prepared to rely on power from other sources in the upcoming hour.

This idea can be accomplished by using cheap and reliable sensors and cameras, spread around a large area; most likely, around a large solar farm. Our goal is to prove this on a small scale with 2 camera sensors and 1 on grid power measurement location. Our choice for the camera will be the Samsung Galaxy S3, because they already have a built in camera and rechargeable battery. This would allow for the use of cellular networks (3g or 4g) to transmit the data to be processed along with having access to other features of the phone such as GPS and a system clock.

This sensor will also be powered by a larger battery connected to a solar panel, to allow for these phones to operate in areas without other power sources. The data from both types of sensors needs to be transmitted with no more than a 10 second latency to a server in order to allow processing and still generate a predict every 30 seconds. This server will analyze the received data and predict future areas of solar insolation, based on cloud coverage.

The second type of sensor will use a power measurement chip and microcontroller with Wi-Fi access. This subsystem will be placed within households that currently have solar panels and will be powered from a standard wall outlet.

1.3 Definitions

Solar Flux- unit of radio emission from the sun, used a measured index for solar activity.

Solar Irradiance-Radiant energy given by the sun over all wavelengths that falls each moment on one square meter of earth's atmosphere.

Solar Insolation-The amount of electromagnetic energy (solar radiation) incident on the surface of the earth. Basically that means how much sunlight is shining down on us.

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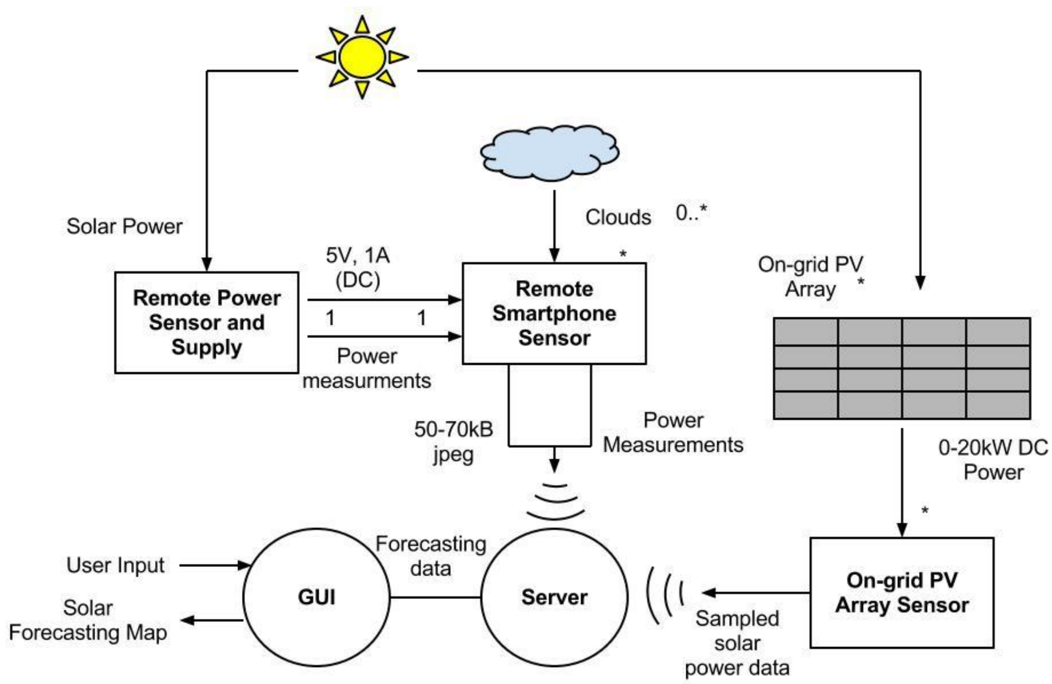
2. Overall Description

2.1 Product Perspective



2.2 Product Functions

Remote Smartphone Sensor:

High Priority:

1) Connects to wireless network. Software: sends data every 30 seconds.
2) Takes photos of the sky every 30 seconds.
3) Records solar irradiance every 30 seconds.
4) PV array connected to smartphone and recharges battery during the day.

Medium Priority:

1) Stays powered for 3 days without sunlight
2) Sensor is scalable and ready deployable.

On Grid PV Array Sensor:

High Priority:

1) Monitors current, voltage, and power and sends data to server approximately every 30 seconds wirelessly.
2) Uses residential WiFi connection rather than 3G/4G connection.

Medium Priority:

1) Powered by the house it is stationed on.

Server:

High Priority:

1) Receives and stores data sent from smartphone sensor and on grid PV array sensor in easily accessible database in less than 30 seconds.
2) Determines cloud motion vectors and solar insulation.
3) Calculates forecast from cloud motion vectors.
4) Forecast times up to an hour
5) GUI displays forecast as a map of solar flux intensity over the area.

Medium Priority:

1) Forecasts are determined at different intervals for up to an hour ahead.

Low Priority:

1) Stores past data for the user to browse.

2.3 User Characteristics

The main user of this product will be the service providers of a power company. This means that they must be capable of using the solar insolation map display and how to change time frame for solar insolation predictions. This requires knowledge of power theory and how to interpret data from the solar insolation map to manage power providing.

2.4 Design Constraints

Remote Smartphone Sensor:

- Is small and mounted well as a safety constraint because it will be high off the ground.
- Connects to a fast, thoroughly spread, and reliable network (3g/4g) wirelessly sending data to server.
- Interfaces with Android using Java.
- Takes pictures using a wide angle lens every 30 seconds.
- Records solar irradiance every 30 seconds.
- Withstands strong weather conditions, increasing reliability.

- Connects to a PV panel recharging battery.
- Battery lasts three days without sunlight.

On Grid PV Array Sensor:

- UART used as a signal handshake between the PV array and the sensor to relay power data.
- Takes power data every 30 seconds.
- Connects to the residential wifi sending power data every 30 seconds to the server.
- Small enough to integrate with the power inverter indoors (inverters are already included with a residential PV setup).
- Powered by 120V, 60Hz available from the grid.
- Handles high output voltage and current from the PV array.

Server:

- Generates forecasts in a maximum of 30 seconds.
- Processes images and on grid power PV array sensor data to create cloud motion vectors and determine solar insolation predictions.
- Displays forecast of solar insolation as a map of the region covered.

2.5 Assumptions and Dependencies

- Data can be transferred every 30 seconds

- Solar insolation can be calculated and presented within a minute
- Adequate funding is granted
- Phone can remain powered for multiple days of cloud cover

3. Specific Requirements

3.1 User Requirements

Remote Smartphone Sensor		
Marketing Requirements*	Engineering Requirements	Justification
1	Small battery connected to smartphone through for power.	Power source needed to recharge battery.
1	Must stay powered for 72 hours without sunlight	System is needed most when there are clouds - it must not run out of battery during these times
4,7,9	Needs to connect to a wireless network (wifi/3G/4G)	So that the phone can send data to the server/database
2,9	Must save picture with relevant data (cloud coverage, power data, geo tag, time stamp).	So that necessary data is received.
2,9	Must send file to server in no more than 10 seconds, every 30 seconds	So that cloud forecasting predictions are up to date.
3-4,7	Temperature regulation must be developed to to heat and cool phone when needed.	Allows the phone to operate longer, in more extreme weather conditions
3-4,7-8	Weather proof casing must be designed	Protects the system from damage,

		simplifies installation

On-Grid PV Array Sensor		
Marketing Requirements*	Engineering Requirements	Justification
9	Must use residential WiFi connection rather than 3G/4G connection	Cheaper and more power efficient than using the 3G/4G connection.
1,6	Powered by the house it is stationed at	So that the unit can continue to operate.
5	Monitors current, voltage, and power output of PV array	Needs to be able to send real time power data to the server
2	Sends data (power) to the same server used by the Remote Smartphone Sensor in no more than 30 seconds, every 30 seconds	To increase the accuracy of the cloud forecasts

Server		
Marketing Requirements*	Engineering Requirements	Justification
2,6	GUI showing a map of the solar insolation over the next hour.	Helps predict PV array power output
2	Needs to have a prediction ready within the minute of receiving the first sensor image.	Predictions have an accurate resolution for smart distributed generation decision making
2,9	Need a server with a database to store and receive data constantly	Computation and storage cannot be done on the phone itself
2,5	Integrate data taken from smartphone and PV arrays to produce forecast	Helps reduce error and give more accurate

		predictions.
2,6	GUI has a feature to adjust time frame to view the forecasted map in time intervals: Current, 1, 5, 10, 15, 30, 60 minute.	Allows the user to see the the calculated predictions in a useful visual.
2	Needs to create motion vectors based off of cloud images.	Essential for insolation forecast.
2	Needs to calculate solar insolation forecast from the cloud motion vectors	Actual insolation forecast

* Marketing Requirements
1. Run off of stored power for at least 3 cloudy days
2. Generate cloud forecasts once every minute
3. Low cost compared to other similar systems
4. Easy installation, maintenance, and system expansion
5. Accurate power measurements
6. System data is readily available
7. Able to consistently operate in a changing outdoor environment
8. System needs to be readily deployable and scalable
9. System must use wireless communication technologies

3.2 Use Cases

Use Case UC1: Solar Insolation Predictions

Scope: Solar Insolation Forecasting (Cloud7)
Level: User Goal
Primary Actor: Power Engineer
Stakeholders and Interests:

- Power Company: Wants to be able to make smart decisions about how they will produce power in the near future.
- Power Engineer: Wants solar insolation predictions to be easily and quickly accessible.
- Power Grid Customers: Wants reliable power provided to them regardless of weather.

Preconditions:

- Remote Smartphone Sensors are distributed across the grid so that entire sky area desired is covered and can be forecasted.
- On Grid PV-array Sensors are distributed across the grid.

- All Smartphone Sensors have reliable data connection.
- All On Grid PV-array Sensors are connected to a reliable WiFi network.

Postconditions:

- Solar insolation predictions are up to date and accurate.
- Predictions are available for up to one hour in the future.
- GUI displays a solar insolation map for a specified area.
- GUI provides tools to view specific prediction times.

Main Success Scenario:

1. Remote Smartphone Sensors take photos of the sky while the On Grid PV-array Sensors simultaneously collects power data.
2. Both sensors send data to the server every 30 seconds
3. Server processes the data to produce a solar insolation forecast.
4. Power Engineer opens GUI.
5. GUI displays the cloud coverage map for the currently selected time
6. Power Engineer(s) uses this data to calculate solar power that will be available.
7. Power Grid customers consume power without interruption.

Steps 5-7 are repeated until nighttime (no sunlight)