Solar Panel Power Output Monitoring System

Choice of simulation environment

In order to simulate power output of solar panel, I decided to look up if there is any appropriate service for forecasting power output of solar panel. This is how I found Solcast API for solar data, as can be seen on their website: https://solcast.com/
I have created home hobbyist account and created „Home PV System“ with location in Bruchsal.
I can query estimates of solar panel power output with HTTP GET request as following:

```
GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi9lDsuRKxWWi3jQApLz&format=json&hours=1
```

Since there are some restrictions of hobbyist account, I can not read estimates of solar panel power output each second.
That is why I simulated Solcast API with Flask server Python, with same format of HTTP GET response as I would get from Solcast API.
Solcast API gives response in JSON format like following:

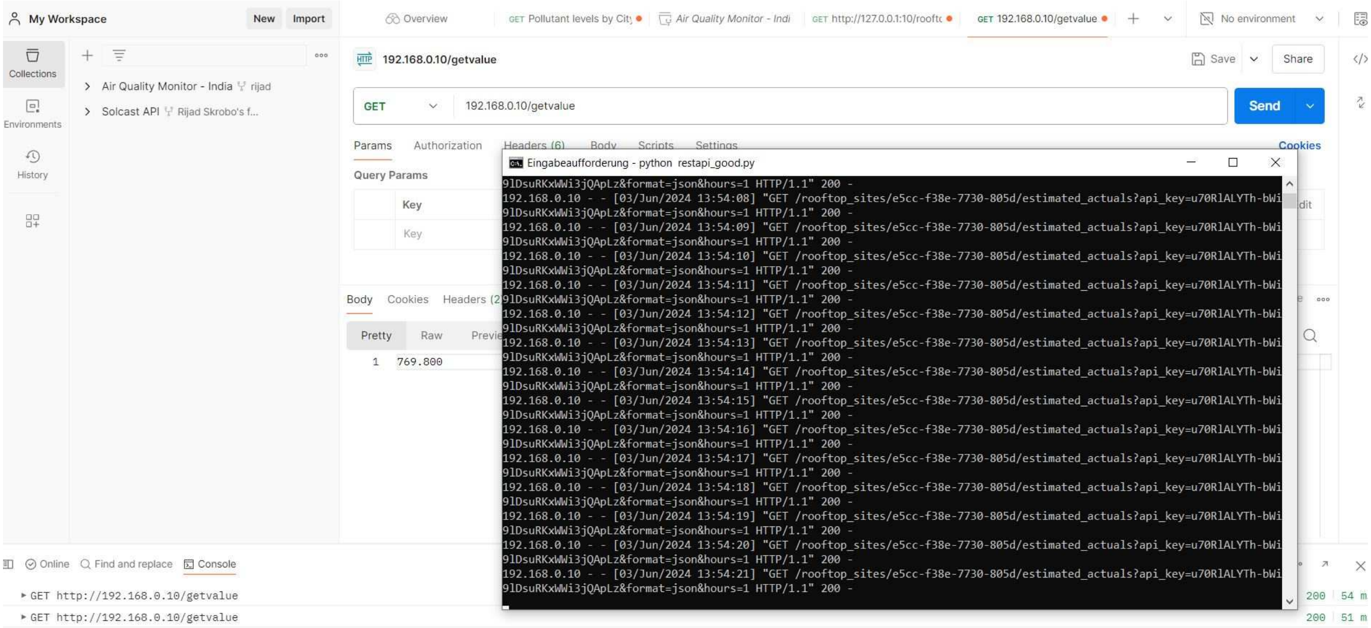
```
{
   "estimated_actuals": [
      {
         "pv_estimate": 0.7698,
         "period_end": "2024-06-01T09:00:00.0000000Z",
         "period": "PT30M"
      },
      {
         "pv_estimate": 0.7155,
         "period_end": "2024-06-01T08:30:00.0000000Z",
         "period": "PT30M"
      },
      {
         "pv_estimate": 0.6189,
         "period_end": "2024-06-01T08:00:00.0000000Z",
         "period": "PT30M"
      }
   ]
}
```

In this case, estimated power output is in kW.
In real case, however, power output would not change each second so much.
I believe that this could be good option to test power output monitoring system, even though we do not have access to solar panel or full access to Solcast API:

Firmware development of solar panel power output monitoring system

In my case, I have used Discovery kit with STM32F746NG MCU, because I already had it at home. Description of this Discovery Kit can be seen here:
https://www.st.com/en/evaluation-tools/32f746gdiscovery.html
I have used lwIP library for developing REST API client and HTTP server on this discovery kit.
I have used cJSON library for parsing JSON string which could be returned from Solcast API.
However, I have hardcoded IP addresses of discovery kit and my computer, but I believe that it could work with DHCP enabled as well.

Firmware is making HTTP GET request once every second and parsing result from JSON string. Parsed power output of solar panel, measured in Watts, can be read from HTTP Server running on Discovery kit.
Running example with plausible power output can be seen at the picture below.



GET 192.168.0.10/getvalue

```
1   769.800
```

```
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:08] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:09] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:10] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:11] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:12] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:13] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:14] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:15] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:16] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:17] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:18] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:19] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:20] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:54:21] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
```

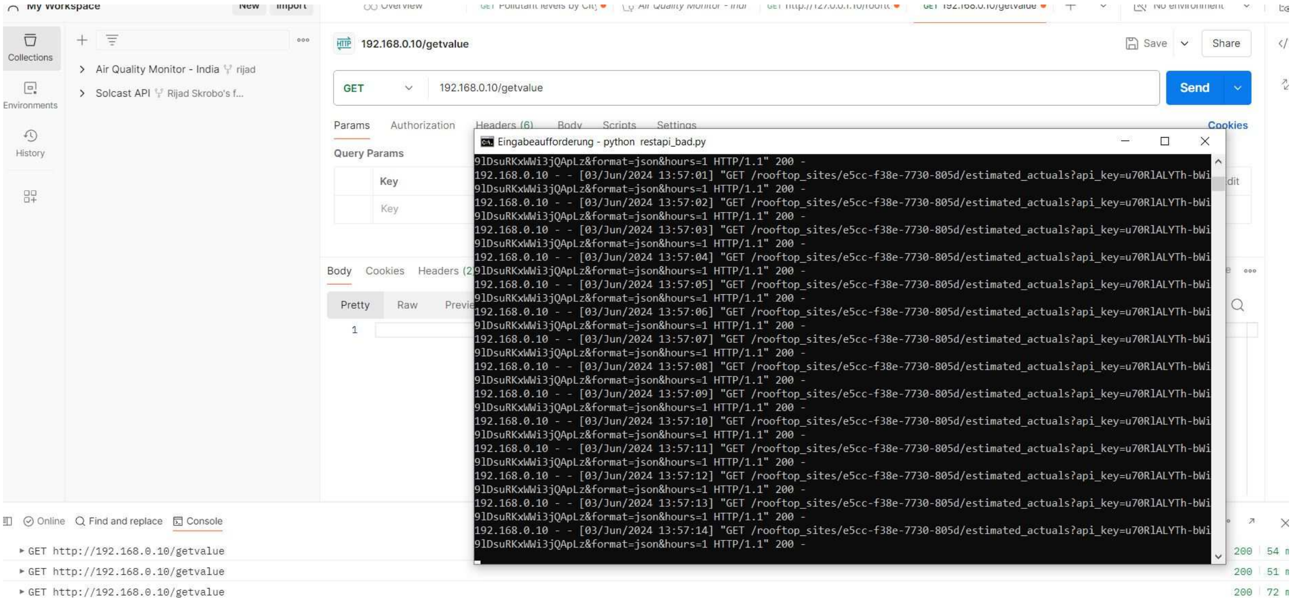
```
▸ GET http://192.168.0.10/getvalue          200 | 54 m
▸ GET http://192.168.0.10/getvalue          200 | 51 m
```

I

In case that power output of solar power is not plausible, HTTP GET /getvalue request is returning dummy value 1, as can be seen at the picture on the next page .

Test plan and test results

In my case, I have only two Python scripts with good and bad JSON response for solar panel power output. It can be extended and automated.
I have used Postman for testing of responses from HTTP server running on Discovery Kit.
This can still be automated, for example with Python script that makes HTTP GET requests to HTTP Server running on Discovery kit.
Still, these two cases are enough to test if system is runnung as expected.



GET 192.168.0.10/getvalue

Eingabeaufforderung - python restapi_bad.py

```
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:01] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:02] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:03] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:04] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:05] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:06] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:07] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:08] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:09] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:10] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:11] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:12] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:13] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
192.168.0.10 - - [03/Jun/2024 13:57:14] "GET /rooftop_sites/e5cc-f38e-7730-805d/estimated_actuals?api_key=u70RlALYTh-bWi
9lDsuRKxWWi3jQApLz&format=json&hours=1 HTTP/1.1" 200 -
```

```
▸ GET http://192.168.0.10/getvalue                200   54 m
▸ GET http://192.168.0.10/getvalue                200   51 m
▸ GET http://192.168.0.10/getvalue                200   72 m
```