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Automated Performance Monitoring Of Multiple Rooftop Systems Using A Single Machine Learning Algorithm

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AIM:

The aim of this work is to develop a machine-learning algorithm, which will have the capability to automatically fetch the performance data of several rooftop systems across a chosen region of interest on a periodic basis. The performance data of every rooftop site will be analysed by comparison to other sites of same installed capacity and compared against the estimated power generation of each site. Estimation data is normally calculated based on site's geographical location, solar irradiance, plant capacity, installation angle of PV modules and other site related aspects. The machine-learning model created with such inputs will be able to generate an output that shows site-to-site and inverter-to-inverter level performance comparison in a graphical manner through a data visualization platform. For the ease of understanding, every site's power generation data is calculated inverter wise as units generated per kilo Watt (kW) by considering respective inverter DC load.

APPROACH:

Microsoft Azure ML studio application was used to develop the machine-learning algorithm to fetch and consolidate the power generation data of all sites through each site's Application Program Interface (API) as inputs. Python script was used in ML studio for data cleaning and structuring as per the required format for performance analysis. Performance comparison was done between selected sites based on generated power, estimated power and Performance Ratio (PR) of each site. Estimated power generation and PR came as another input data into Azure ML studio and this was compared against actual generation and PR of respective site. Output data from Azure ML studio model was written to Azure SQL database after creation of specific credentials for automatic data transfer. Graphical visualization of output data was done using Microsoft Power Business Intelligence (BI) tool.

As shown in Figure.1, each site has three API's that fetches sensor, inverter and site related information. Respective data from each API block was fed as inputs into Azure ML studio for data consolidation and computation. The compiled output file from Azure ML studio was pushed to Azure SQL database for data storage. Finally, Power BI tool was used to create multiple dashboards that represents rooftop performance in the following format:

i. Region wise
ii. Site wise
iii. Inverter wise and corresponding yield loss in kW due to inverter downtime

SCIENTIFIC RELEVANCE:

From this analysis, it is possible to monitor the performance of several rooftop sites across the country by a single click of a mouse button. Since all the tools used in this work are based on Microsoft's cloud storage solutions, it is possible to access, modify or scale-up the algorithm, database and graphical visuals of generated data at any point of time from anywhere in the world. The present manual process of downloading performance data from central data server, data compilation and analysis takes too much time and practically cannot be done in a company, which has more than 800 rooftop sites spread across the country. This will result in delays in taking corrective actions as most of the under-performing sites data will go un-noticed or until the customer raises a concern of non-performance of their site.

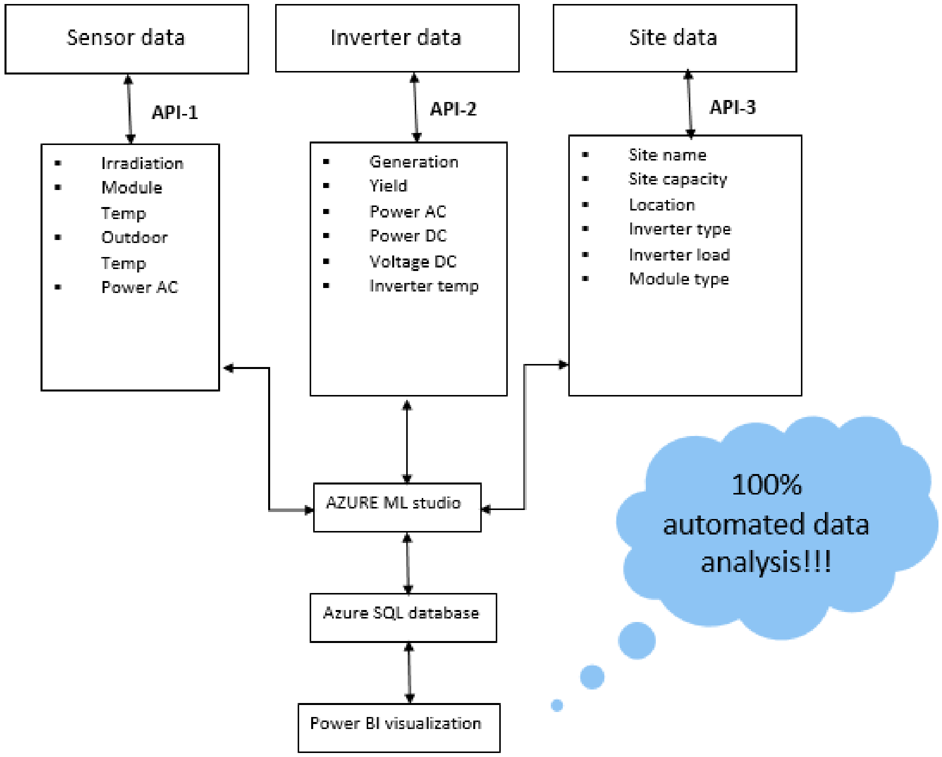

Figure.1 Process flow chart of automated performance monitoring of each rooftop site using ML model

PRELIMINARY RESULTS:

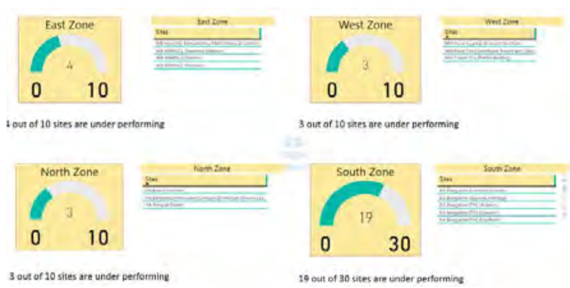

Figure.3a Region wise generation performance data

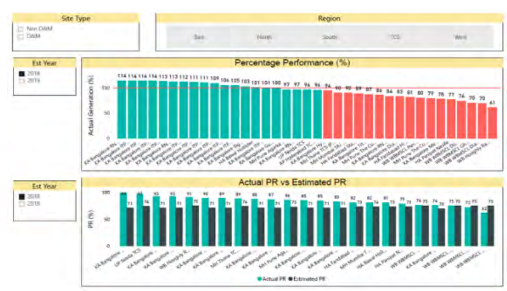

Figure.3b Site wise generation performance data

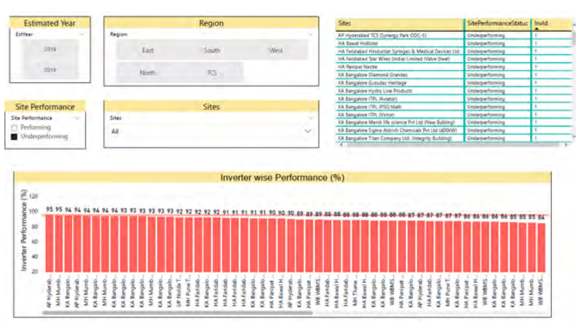

Figure.3c Inverter wise generation performance data

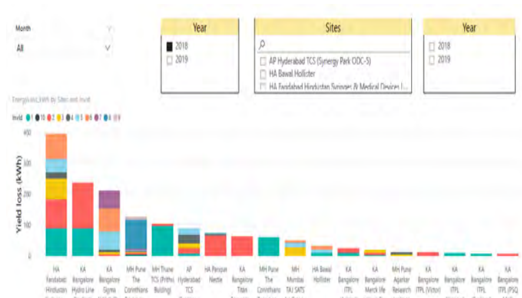

Figure.3d Inverter yield loss (in kW)/year data

Figure.3 Schematic of different dash boards for automated rooftop performance analysis and monitoring

FORMULAS AND LOGICS USED:

- Performance generation (%) = Total generation / Estimation generation
- Site performance (%):
    - *Total generation > 95% of Estimated generation : "Performing"*
    - *Total generation < 95% of Estimated generation : "Under Performing"*
- Inverter performance (%):
    - *Inverter generation > 95% of Maximum generation : "Performing"*
    - *Inverter generation < 95% of Maximum generation : "Under Performing"*
- Inverter yield loss (kWh): *Average Inverter generation (kWh) * Inverter downtime (days)*

CONCLUSION:

An automated approach for rooftop systems performance monitoring and analysis is reported in this work. Manual data compilation and analysis for multiple rooftop sites, which normally takes hours, was compiled and presented here quickly using machine-learning techniques. The final output was presented using dashboards at a click of a button for the end user. The idea behind this work was to eliminate the tedious process of manual performance monitoring and automate this process; thereby the end user could focus on other tasks like identifying the root cause for any non-performance and take corrective action to improve a system performance in a pro-active manner. This approach also helps to minimize the electrical power and subsequent monetary losses incurred to a customer due to a system non-performance and thereby increasing the revenues in the form of new Operations and Maintenance (O&M) contracts and maintaining a good brand image for the company.