OPERATIONAL SOLAR POWER FORECASTING FOR SAFE AND RELIABLE PHOTOVOLTAIC GRID INTEGRATION IN SINGAPORE

PROJECT SUMMARY

BACKGROUND

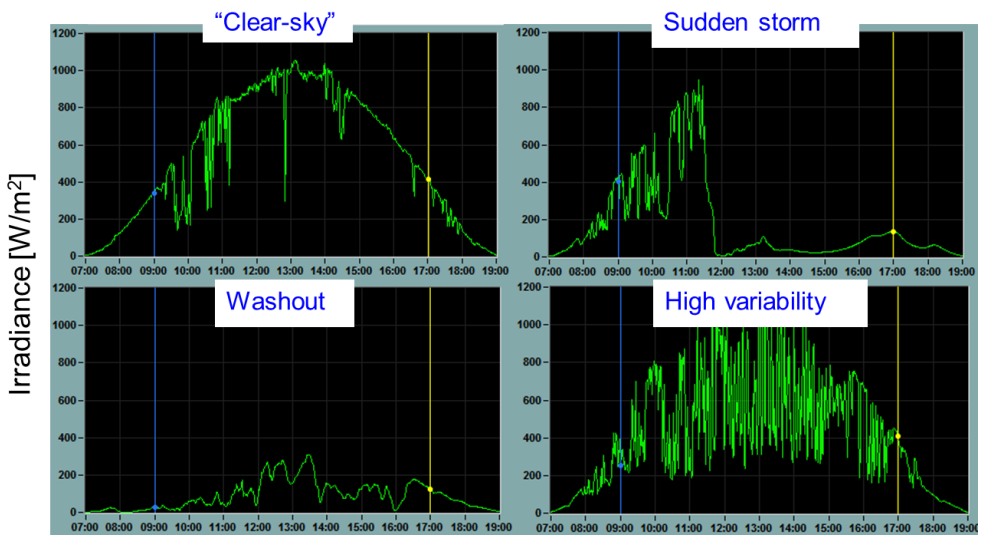
- **Solar** is a key driver for sustainability and carbon emission reductions as described under the Singapore Green Plan 2030.
- The cumulative installed solar photovoltaic (PV) capacity in Singapore **is targeted to increase to 1.5 GWp by 2025 and beyond 2 GWp by 2030**.
- Unlike conventional gas-fired power plants, **solar power is not "dispatchable"**, and its power generation depends on environmental and weather conditions such as cloud cover and humidity.

PROBLEM STATEMENT / CHALLENGE

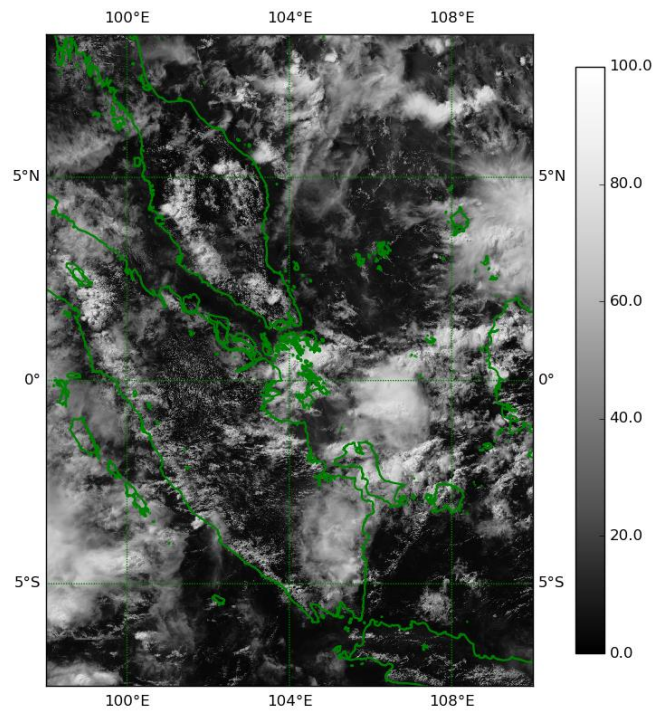
- Given this variability, it is critical for Singapore's reliable power systems operation to be able to **accurately forecast the solar power injection into the grid at various future time horizons, ranging from a few minutes to several hours and day-ahead.**
- Singapore is located in the Intertropical Convergence Zone which is characterized by accumulated moisture in the air and the frequent formation of cumulus clouds (and subsequent thunderstorms). Due to this complexity of our **local weather systems, forecasting the solar power output in Singapore, especially over long time horizons, is very challenging.**

PROJECT OBJECTIVE

- Develop a robust and fully operational solar power forecasting system, customized to Singapore's weather conditions, with 99.9% uptime.



Typical irradiance phenomena observed in tropical Singapore: "Clear-sky" (which still has certain drops due to some cloud formations; "Sudden storm" (e.g. Sumatra squalls); "Washout" (continuous rain over the whole day); and High Variability" (which happens due to turbulent weather conditions and frequent changes in cloud cover). Note that these daily irradiance profiles are for a single station. There is s a smoothing effect from multiple stations, making the overall effects eventually less pronounced.



Satellite imagery enables early cloud identification and weather pattern formation detection over South East Asia. The clouds are projected forward in time using wind speeds and cloud height estimates from the NWP to estimate their future position.

PROJECT OUTCOMES

KEY ACHIEVEMENTS

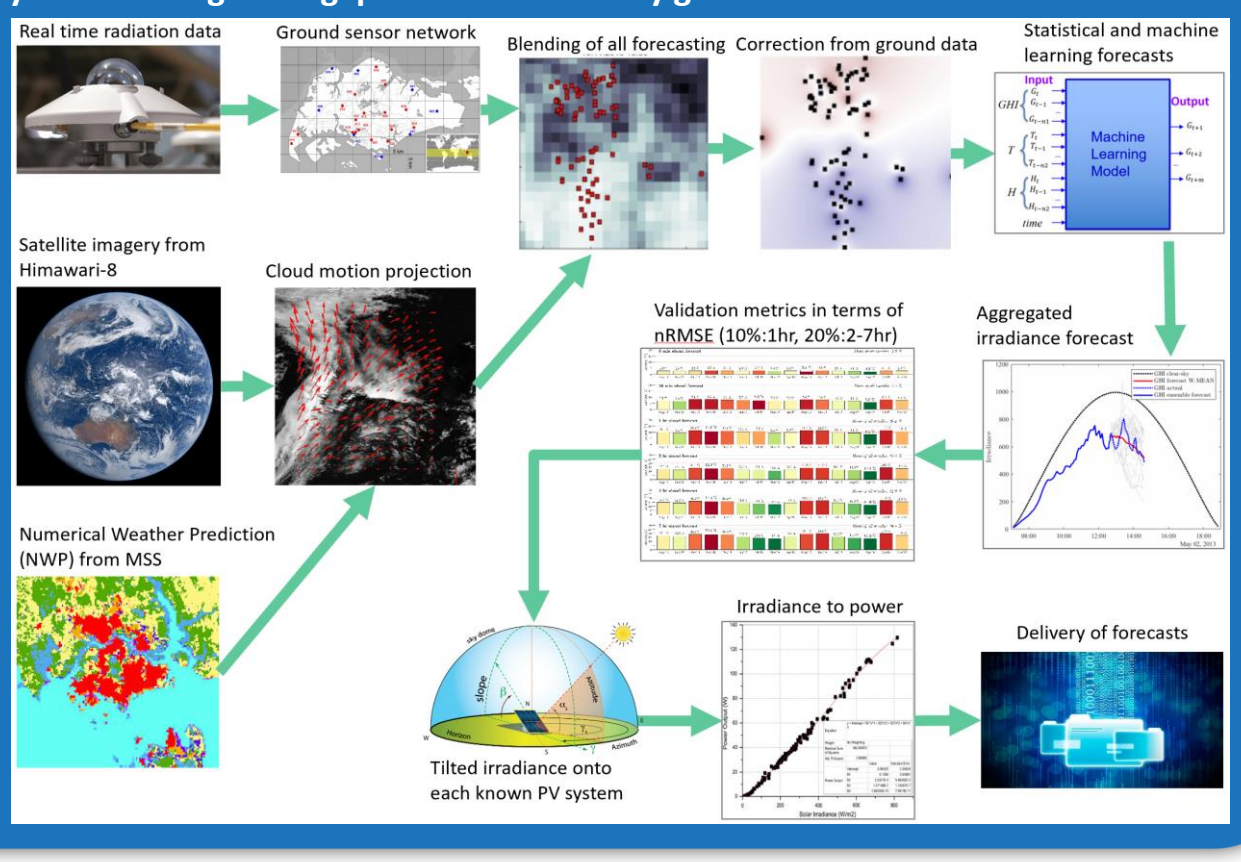
- **SERIS has designed and developed a robust and fully operational solar power forecasting system** that is being trialled and subsequently to be deployed by EMA's Power Systems Operator. **Every 5 minutes**, a sophisticated sequence of solar forecasting techniques using all available real-time data streams (e.g. NWP, satellite, ground data) are calculated, resolved and delivered in minutes.
- The developed model uses a **rapid resolution of over 8 different dynamic and complex solar forecasting techniques**. The techniques combine ground data streams from statistical satellite imagery processing, physical satellite imagery processing, numerical weather prediction, ground data techniques, climatological values and combination approaches.
- **Superior machine learning blending approaches ensure the best possible combination of forecasting techniques**, which is parameterised daily to ensure the best performing techniques are prioritised. These blending approaches account for the current time of day and the forecasting horizon targeted.
- **Grid impacts due to increasing PV penetration are examined** with power system analysis tool PowerFactory. A list of studies **including load flow, quasi-dynamic, short circuit and transient studies**, are performed on a few typical distribution networks. Different mitigation measures are proposed and verified in the simulation studies.

BENEFITS TO SINGAPORE

- The **developed model has achieved the target of 10% normalised root mean square error for hour-ahead forecasts** and 20% for 3 hour ahead forecasts – **making this solution suitable for tropical climates**.
- The ability to anticipate and account for significant ramps up and down in solar power enable Singapore to increase the solar PV penetration across the country, thus, **directly contributing to Singapore's sustainability goals**.

FUTURE PLANS

- To improve and refine the accuracy and robustness of the solar forecasting techniques.
- Push the boundaries of machine learning for the blending of the forecast ensemble.
- **Work with industry players to commercialise the operational solar forecasting system**.



Overview of the entire solar power forecasting system, staring from various input parameters to blending of various forecasts using machine learning for ensemble improvements and eventually conversion of irradiance to power.

PRINCIPAL INVESTIGATOR

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