Risk aware resource planning for microgrid connected edge data center with renewable energy production operating under grid power constraints

Rickard Brännvall*
Sebastian Fredriksson*
Johan Gustafsson*
Lackis Eleftheriadis†

*RISE – Research Institutes of Sweden
†Ericsson Research, Sweden

Outline

- Background
- Edge data center microgrid set-up
- Data sources
- Modell description
- Numerical and experimental results
- Conclusions

What we mean by edge data center

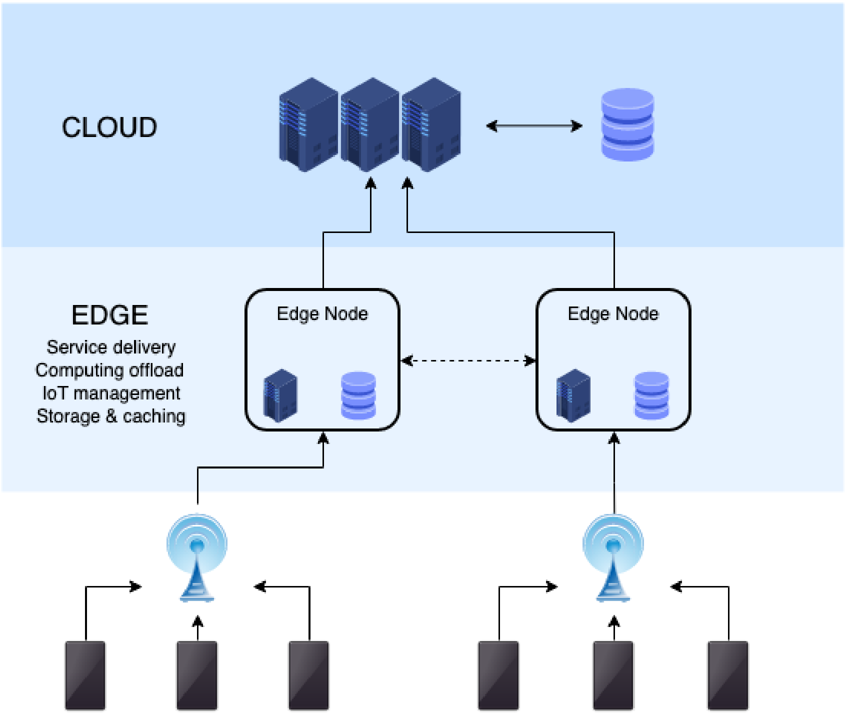
Networked EDGE DC connected to power grid.

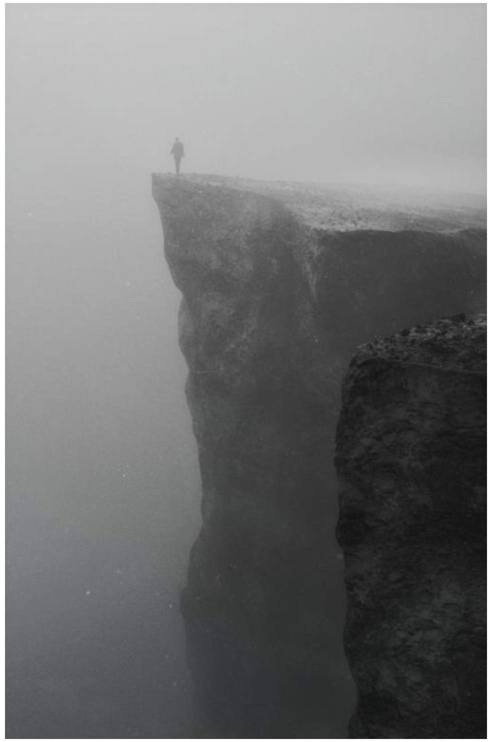
- 5-50 kW power
- EDGE ≠ IoT

Latency requirements will “force” most EDGE DC into cities

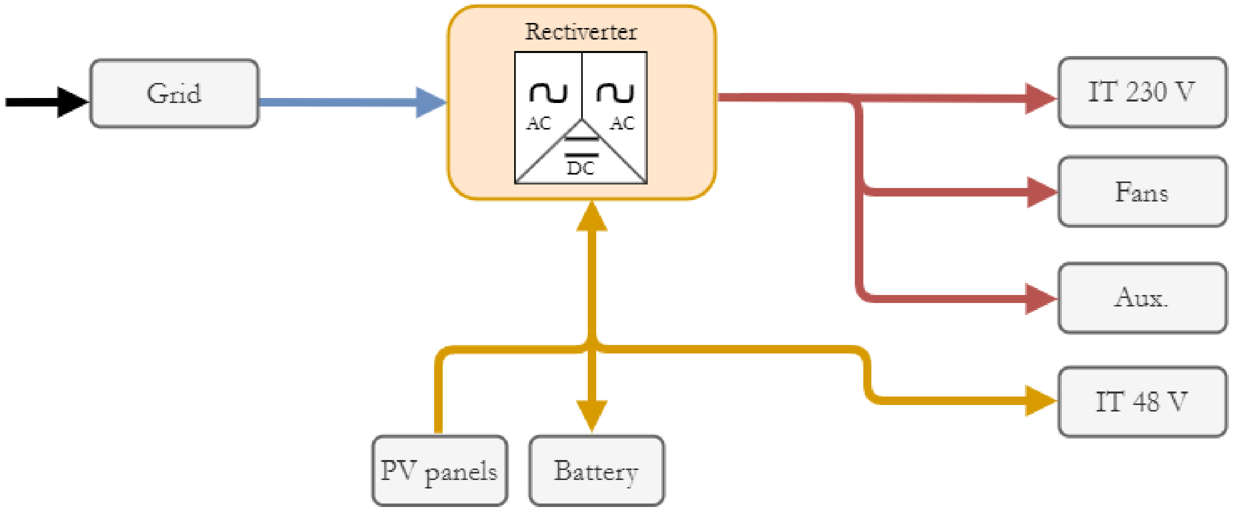
- Land – Difficult and expensive to build.
- Power – Availability, quality

How does the power constraints influence the software running on the EDGE DCs?



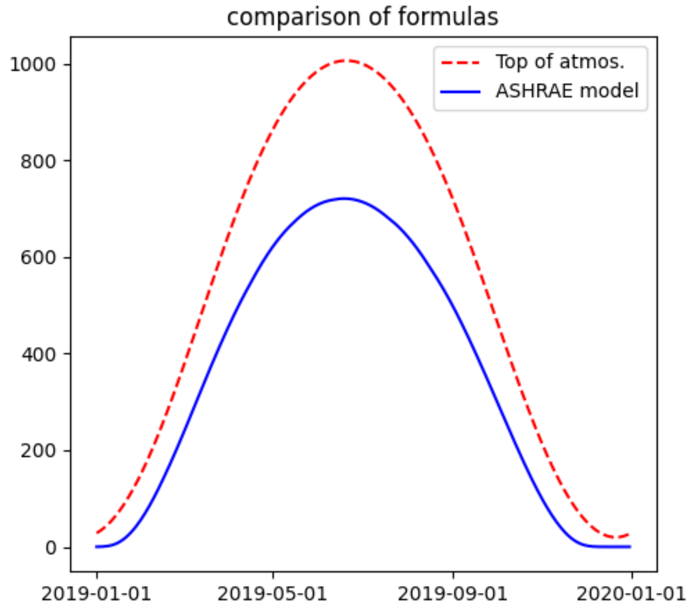


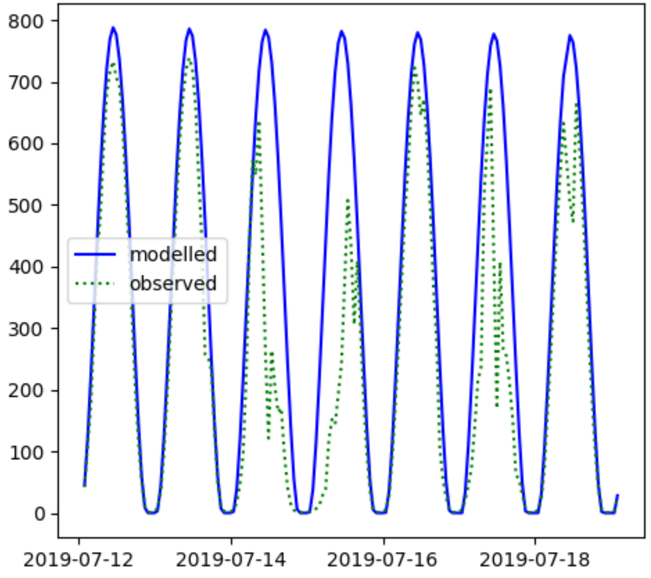
Microgrid edge data centre set-up



- Centered on the rectiverter, a versatile UPS component
- Handles both way AC to DC conversions
- Flexibility in the use of battery, grid and PV
- Both AC and DC loads for servers and cooling

Clear-sky irradiation models





Theoretical maximum of solar energy reaching Earth's surface

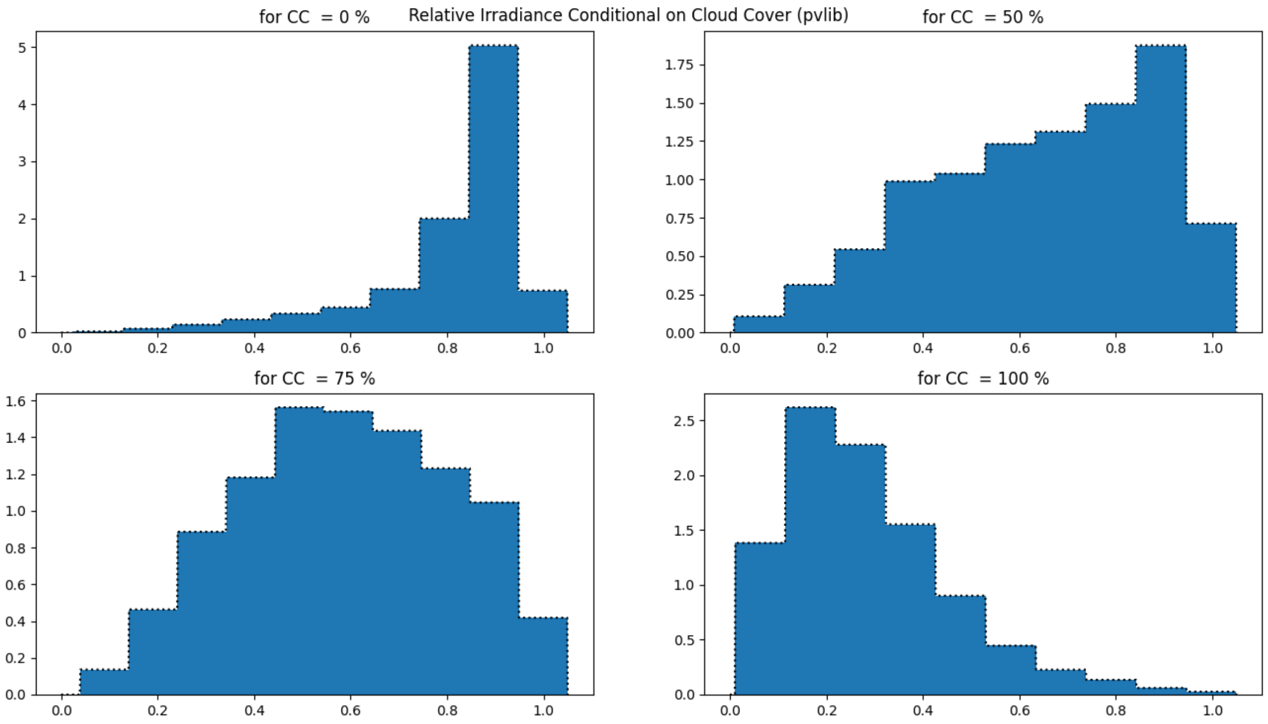
- seasonal factors
- time of day and year
- solar cycle, etc

We also know in advance the

- angle of incidence
- height above the horizon
- tilt of the measuring surface

Missing local ambient and atmospheric conditions.

Public data sources



Public data from the Swedish weather services (SMHI)

Data driven approach
- Observed irradiation
- Cloud cover percent
- Weather "symbol"

at Luleå site

Empirical (stats) relations for modelled quantities,
i.e. conditional probabilities

Probabilistic model using forecast

SMHI provides a probabilistic public weather forecast with three scenarios.

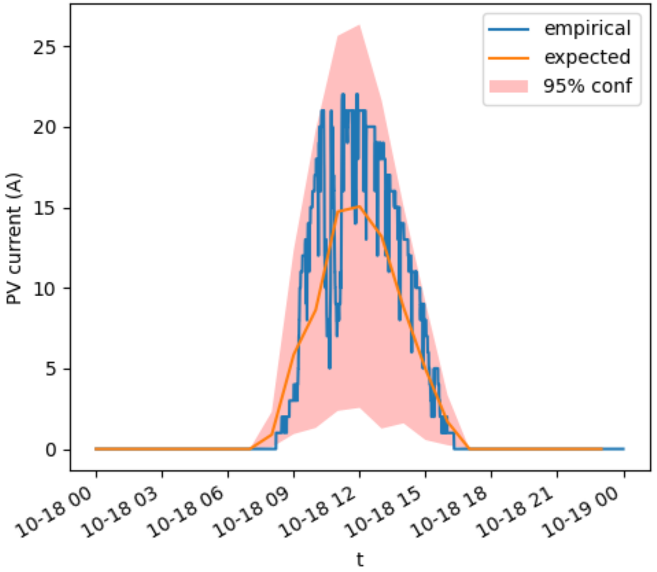
Model local irradiation as a Markov chain

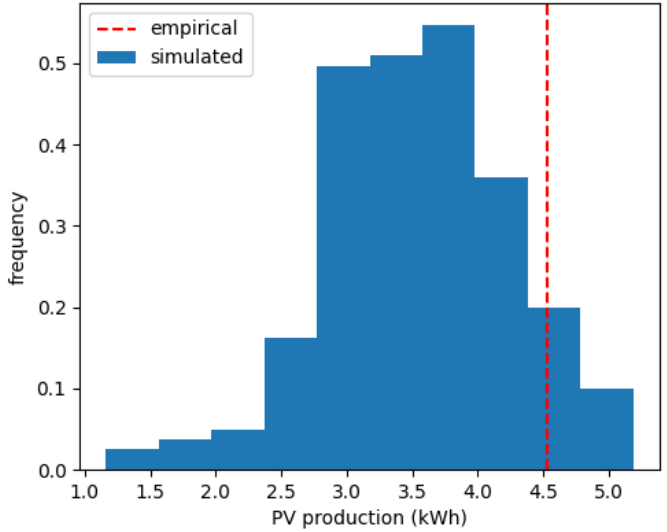
- Derive transition kernel (between weather symbols) from public forecast.
- Estimate maximal irradiation from clear-sky model (season and time of day).
- Scale relative irradiation by sampling from empirical cloud cover distribution.

Algorithm 1 Simulation algorithm

for $i \leftarrow 1$ to N **do**
    for $j \leftarrow 1$ to T **do**
        Sample the next weather symbol, S_{ij} from the Markov chain transition probabilities at t_j.
        Sample cloud cover, c_{ij}, conditional on weather symbol from its empirical distribution.
        Sample relative irradiation, r_{ij}, conditional on cloud cover from its empirical distribution.
        Calculate the clear-sky irradiation from the theoretical model, $\hat{I}_{ij} = I_{\text{model}}(t_j)$.
        Obtain the predicted (absolute) irradiation by multiplication, $I_{ij} = \hat{I}_{ij} r_{ij}$.
    end for
end for

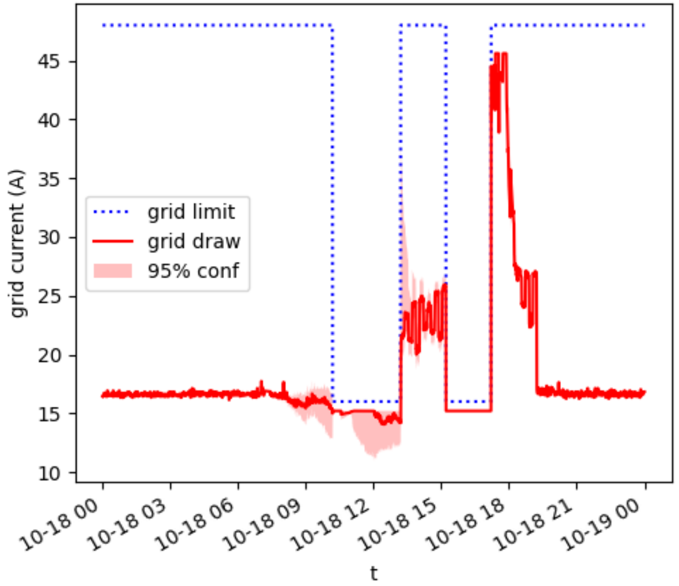
Monte Carlo simulation

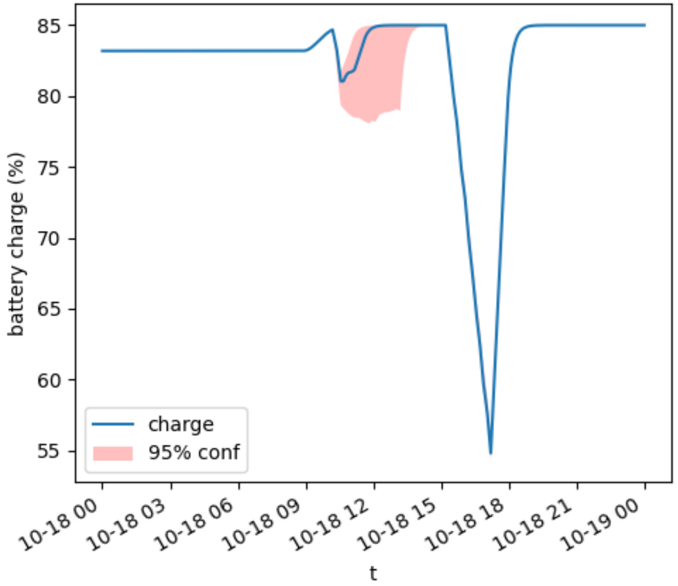




- The local model forecast solar production with confidence bands.
- Histogram of electric production in kWh over simulated forecast.
- The actual production over the period in red.

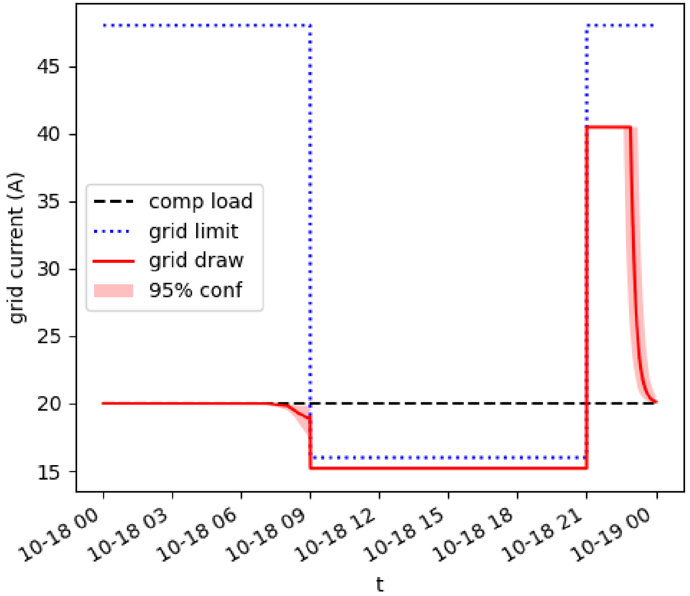
Risk-aware planning (experiment)

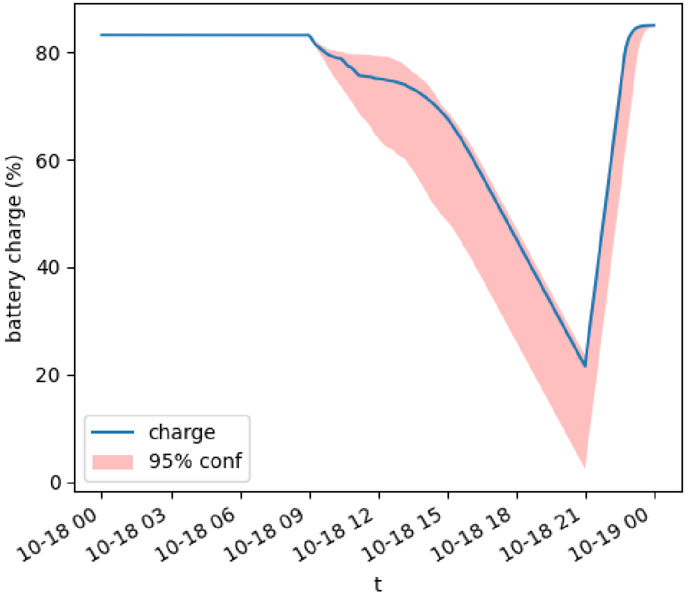




- Experiment with a variable computational load and grid current limited to 16 A during part of the day.
- The actual battery charge stays within the forecast confidence bands over the studied period.

Risk-aware planning (simulation)





- Alternative simulation where 16 A limit stretches from 09:00 until 21:00.
- The system can support a load of 20 A over the day.
- Battery stays within operating limits at 95% confidence forecast .

Conclusions

- Experiments on a small microgrid connected edge DC with photovoltaic production are conducted to compare the model results with actual observations.
- The set-up can accommodate a 20 A IT load throughout a day, while limiting the grid draw to 16 A during a 12-hour window without exhausting the battery (at 95% confidence).
- Solar power can play an important role and improve and extend services by effective risk-aware resource planning allocation.

Comments, feedback, questions...

… thank you

rickard.brannvall@ri.se