AIM SEA | Associazione Italiana delle Macchine a fluido e dei Sistemi per l'Energia e l'Ambiente

Mini Grid Day Sapienza University Rome
21st of June 2018

University of Pisa – DESTEC

FS4MGO International Research Group

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SPEAKERS:

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UNIVERSITÀ DI PISA

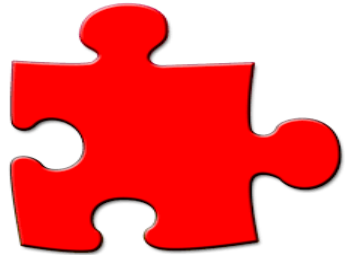
UniPI and FS4MGO

- *Field Study for Mini Grid Optimization*, a strategic research synergy among:
  - **planning** know-how
  - **operation** expertise
  - a wide and consolidated presence on the **field**

- *Planning* requires **fast** but **realistic** scheduling tools
- *Operation* aims at **optimizing** the short-term scheduling of resources, but **computational requirements** can be prohibitive
- *The field* provides **real data**, but existing plants are often **oversized** or operated with **very simple operating rules**

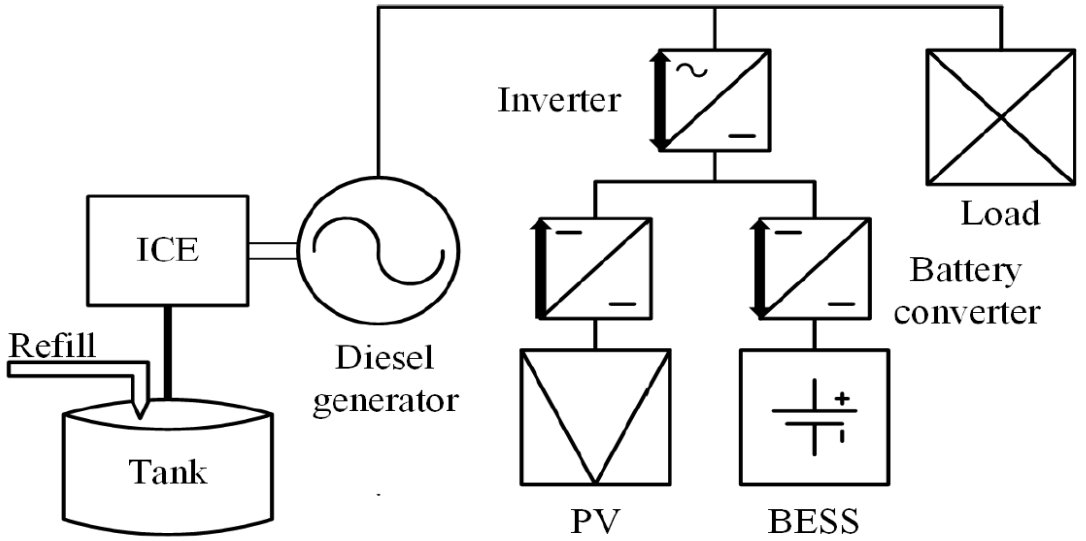
Our role in FS4MGO

The system operation and the social drivers of demand



- Background in the analysis, reliability assessment and optimal and secure operation of large power systems
- Application to smart grids and VPP → isolated mini-grids
- Keywords:
  - **<u>Simulation</u> of the power system:** the yearly operation of different size scenarios
  - **<u>Optimization</u> of dispatchable resources:** basic priority rules (load following, cycle charging, …) are replaced by a rolling-horizon scheduling optimization
  - **<u>Probabilistic</u> approach:** Monte Carlo for load, RES and fuel delivery uncertainties
- Field-related approach:
  - Experimental activities
  - Load profiles and evolution
  - *Correlation with socio-economical aspects*

The considered mini-grid



The mini-grid is sized by **searching the set of components,** whose **yearly operation** is expected to be **the cheapest one**, accounting for:

- investment costs
- operational (fuel) costs
- the economic value of expected load curtailment

The basics of our algorithms: 3 loops

1) An external Particle Swarm Optimization (PSO) procedure properly selects the size scenarios

2) A year of operation is simulated S times according to a Sequential Monte Carlo (MC) procedure

Rolling horizon optimal dispatching

3) Every 6 hours, the load and PV power profiles expected for the following 24 hours are used by a MILP procedure that optimizes the use of resources

- At each time step, the MC procedure draws possible real-time **deviations** from expected load/PV patterns; priority rules correct the real time dispatching

3) The operational costs of the current year are evaluated

2) The Net Present Cost (NPC) of the current size scenario is assessed, based on obtained CAPEX and OPEX

1) When PSO convergency is reached, the size scenario with the lowest NPC is chosen as the best design of the mini-grid

Selected references

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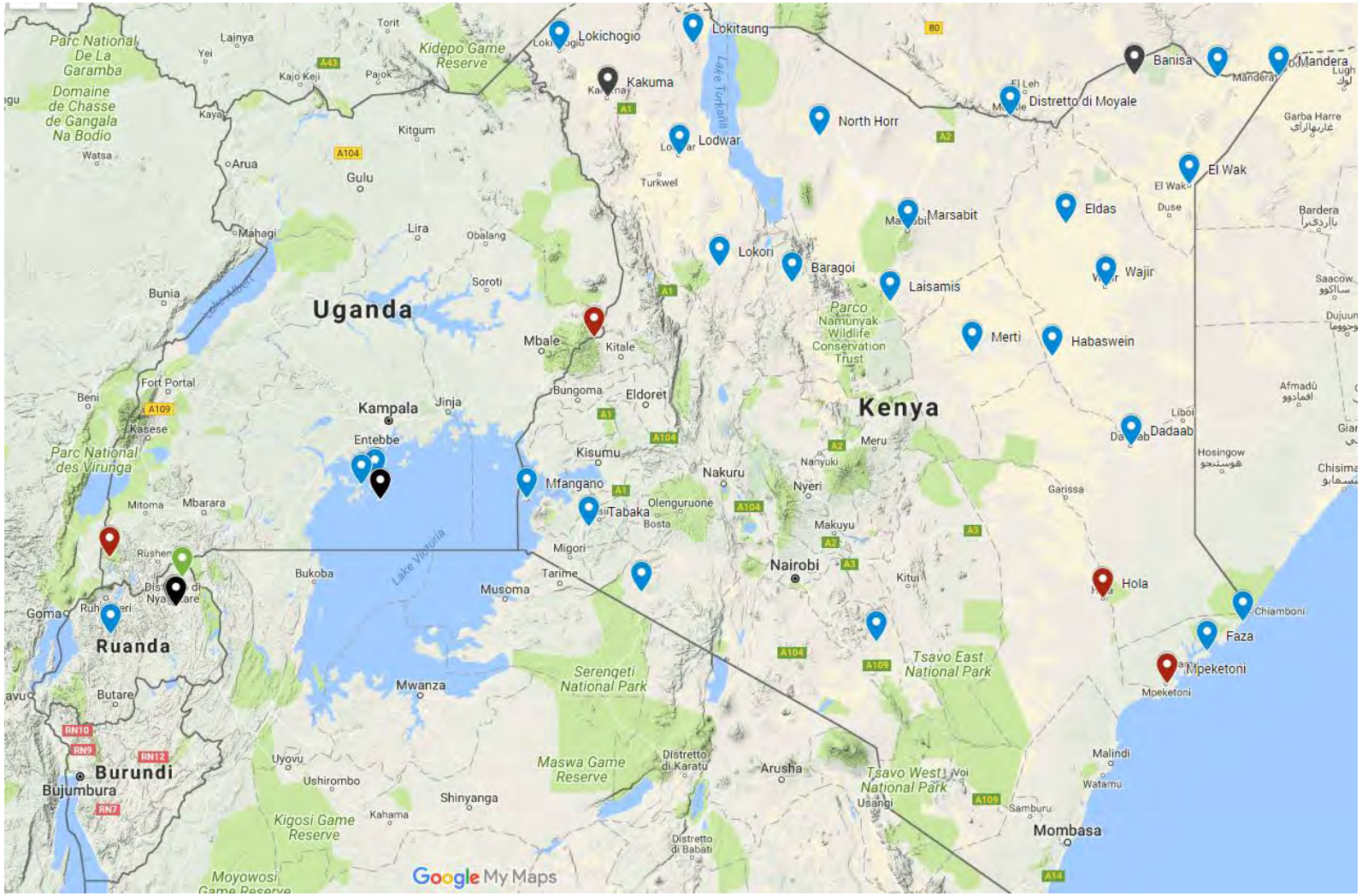
Future developments

- Integration with planning tools (R.E.M.):
  computational requirements and accuracy of different algorithms
- Multi-year scenarios, modularity, long-term adequacy
- Short-term and long-term load forecasting
- Thermal uses
- Social analysis and correlation needs-loads

Micro-Grid Plants Database

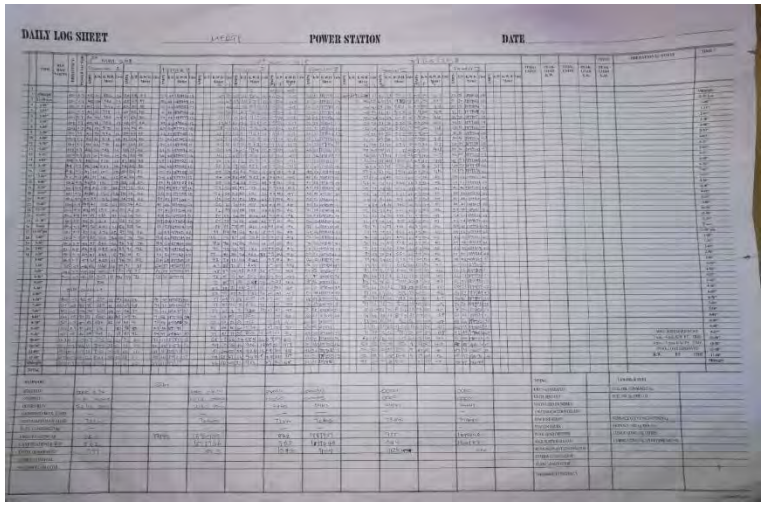
- 34 plants across **Kenya**, **Rwanda** and **Uganda**. We are also obtaining data access to 3 plants in **Tanzania**.
- The group is also active in Central America, and we are in the process of installing remote monitoring in three micro-hydro plants in **Honduras**



Light Blue: in Operation; Black: in construction/commissioning Red: now grid connected Green: still greenfield

Types and diversity of data

- Some sites were followed since the greenfield phase (baseline surveys), other are assessed ex-post
- **Installed power**: spanning from 11 kW to 1.6 MW.
- **Business models**: some are privately owned and some are community-based
- **Technologies**: some are diesel-based with various degrees of hybridizations, others are purely hydro, others PV based with DG and BESS (lead acid, lithium, **VRFB**)
- **Data acquisition**: Some of them are not monitored at all, others have paper logsheets, others have digital monitoring of energy production, meteorological conditions… with granularities ranging from 10 seconds to 15 minutes

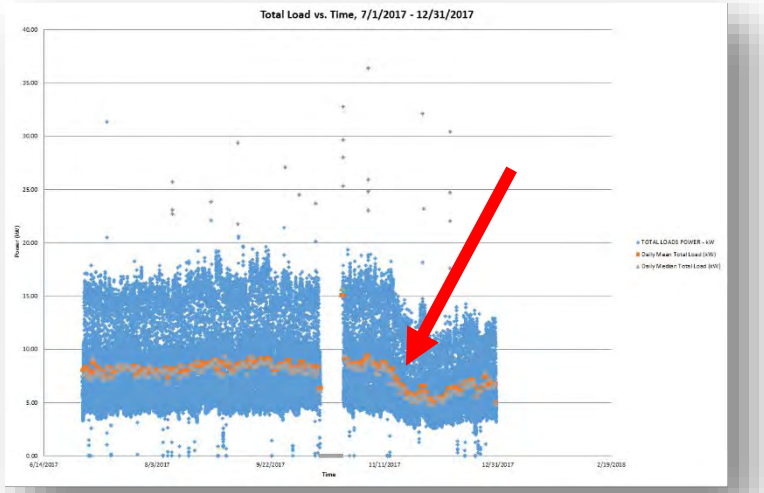


A logsheet used by KPLC in Kenya for their off-grid sites

The web portal used by Talek Power

Methods and goals

- Having direct contacts with the communities is not only needed to collect the data that would not be available otherwise, but also to **interpret correctly data** that is acquired remotely

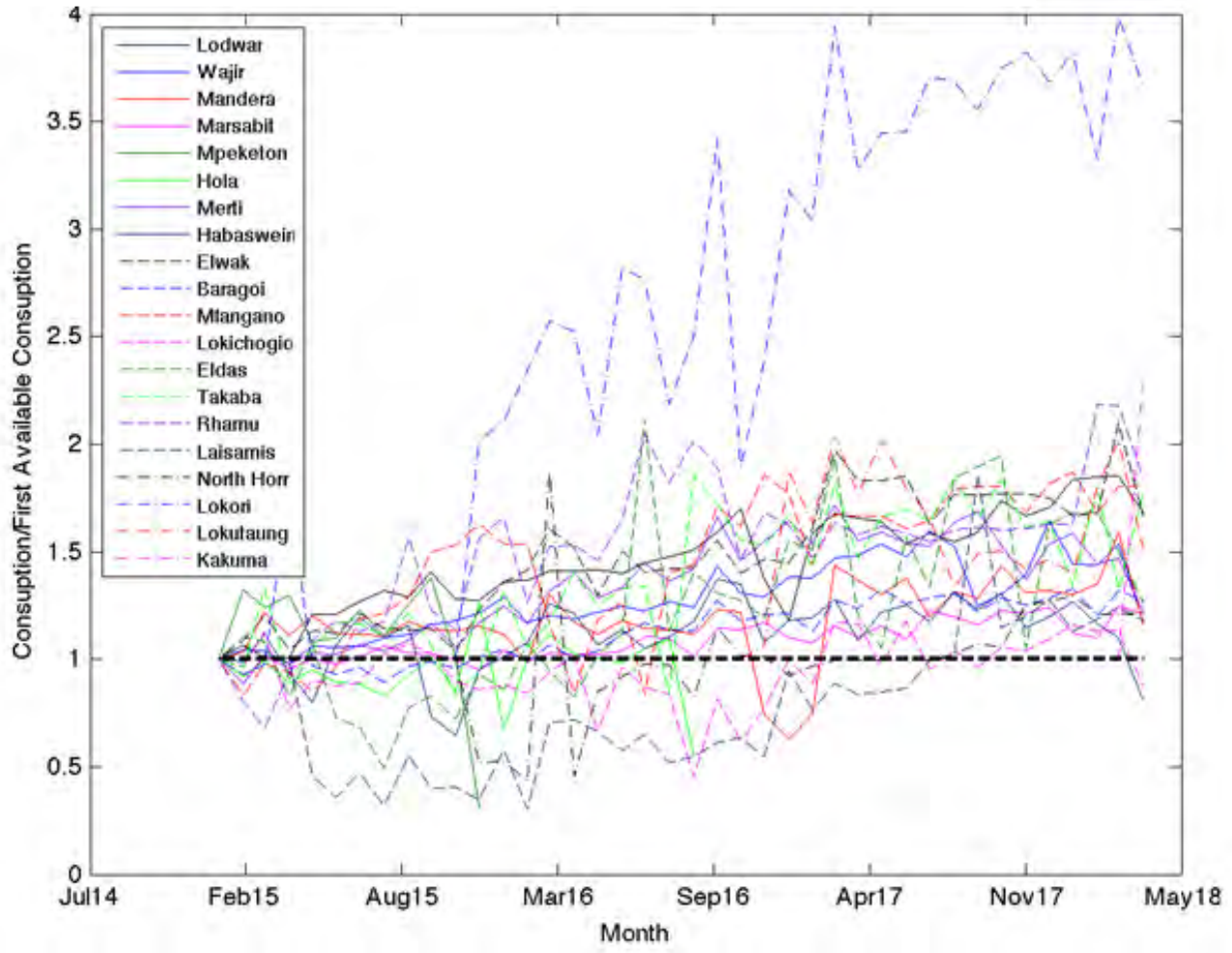


Fishing ban enforced by the Ugandan military and it's effect on the community load curve of an Island on Lake Victoria

- Building a comprehensive database of consumption data (community-wise and for some single, "typical" user) to evaluate **demand evolution patterns** and **parametrize load profiles** with socio-economicall indicators;
- **Validate methodologies** (the effectiveness of load estimation on greenfield sites) and **models** (comparing the results of different optimization codes to improve them with real-life evidence and optimize the design and operation of real-life plants to make micro-grids more viable for achieving universal energy access)

First results

- We recently obtained the soft copies of monthly reports for more than 20 microgrids, which will allow for a first assessment of demand evolution for these communities, which will be done in greater detailed when daily profile evolution will be made available.



«Normalized» consumption profiles for several Kenyan microgrids