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Can greedy customers be good citizens?

Coordinated distributed energy resource optimization via power flow simulation.

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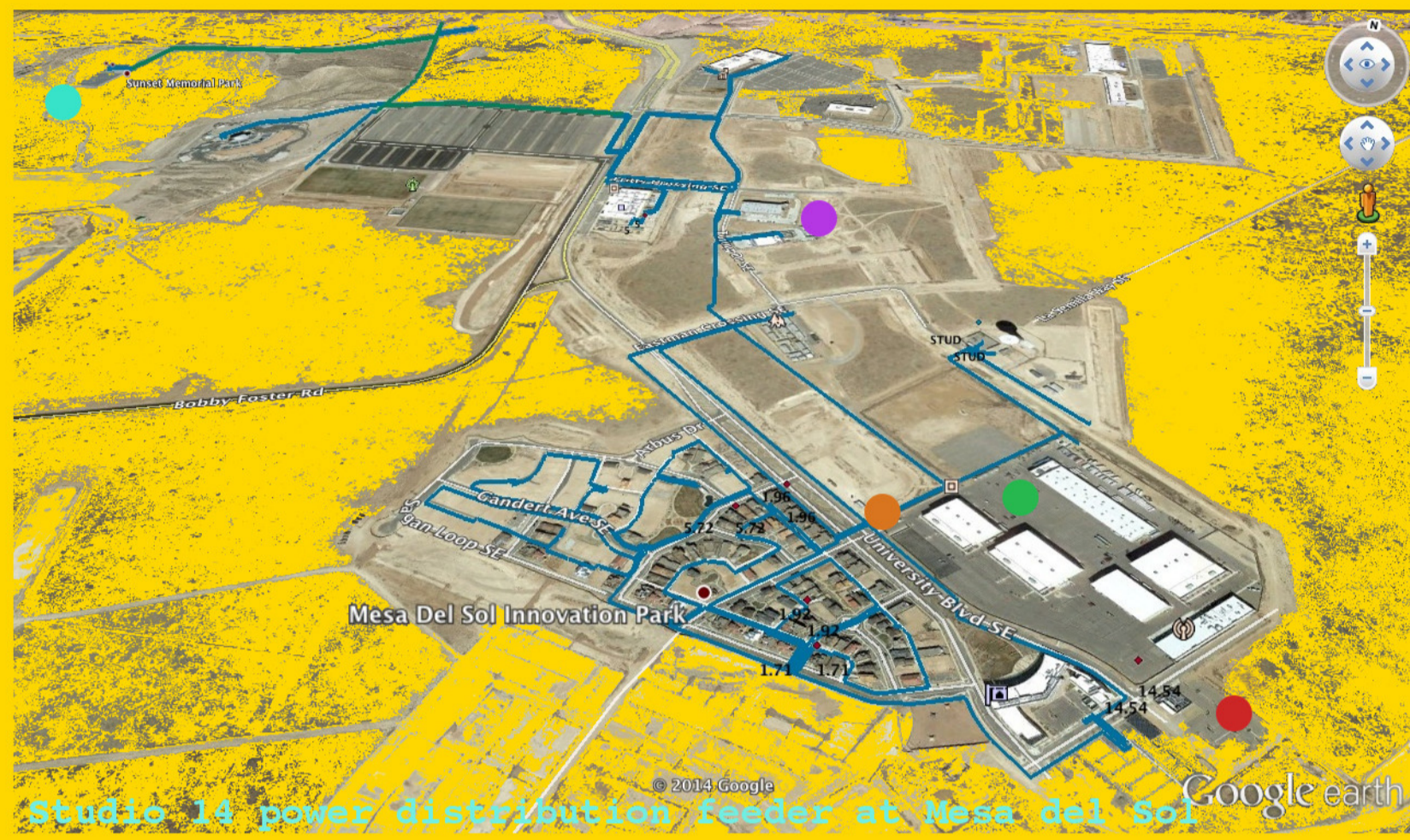
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Purpose

Power distribution feeders are the building blocks of the future smart grid. Eventually, it is possible that feeders will morph into microgrids. Distributed energy resources located on a specific feeder should act in a coordinated way, to ensure that the overall system functions in an efficient and economical way, without disruptions in power quality driven by collective action of individual optimizations. The problem is how to encourage owners of DERs to operate their facilities in a grid-friendly way, without affecting the economics in a significant way.

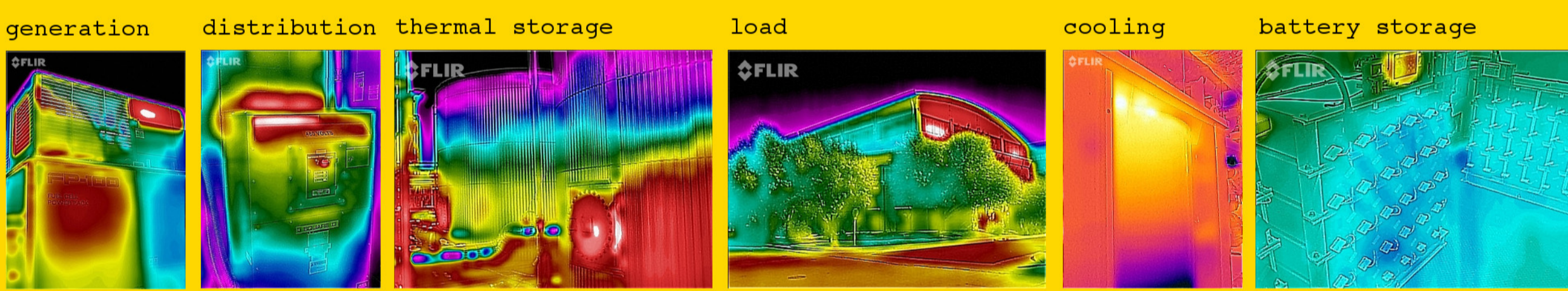
To optimize the operation of individual DERs, Berkeley Lab's Distributed Energy Resource - Customer Adoption Model (DER-CAM) cloud-based system is an attractive option. However, the customer-centric optimization should be tempered by information derived from the power flow on the feeder.



DERs

- UNM Mechanical Engineering: solar assisted HVAC, hot & cold TES, absorption chiller
- Aperture Center: microgrid with PV, battery, NG genset, fuel cell, hot & cold TES, electric chiller
- Albuquerque studios: electric chillers and ice TES
- PNM Prosperity site: distribution-scale PV with battery storage
- One Sun Plaza campus: building with PV, electric chiller and cold TES

The Studio 14 power distribution feeder, located at Mesa del Sol, a planned community in Albuquerque, New Mexico (USA), currently hosts several facilities with advanced DERs, including a solar PV array with battery storage, a commercial building served by a microgrid, and movie studios with large ice storage. It is almost certain that, as the Mesa del Sol community grows, there will be an increasing number of facilities with advanced DERs connected to the Studio 14 feeder. Moreover, it is also likely that each of these facilities will take advantage of cloud services for minimizing operating costs. In this study, we consider this future situation and investigate the implications of such a situation.

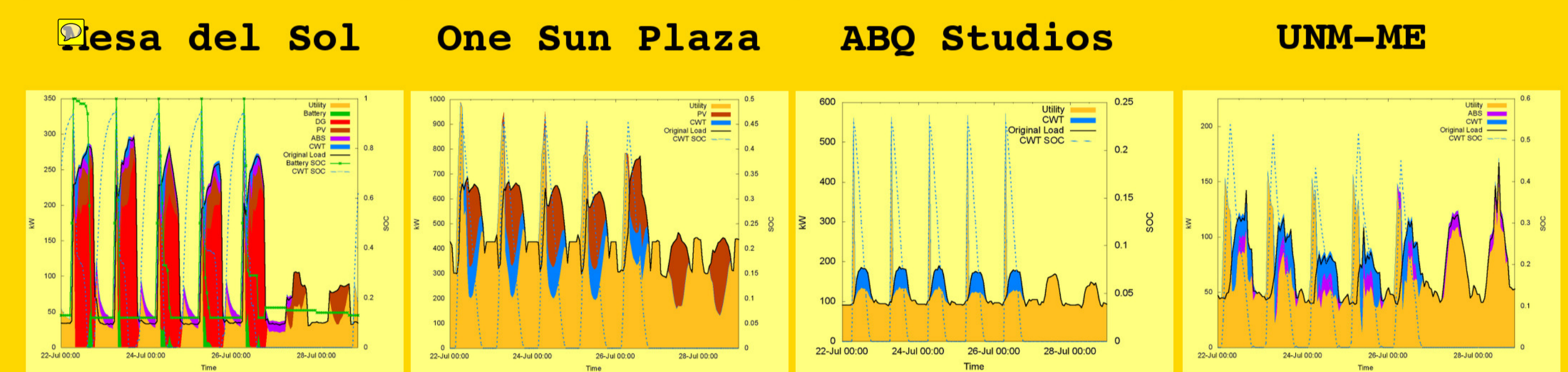
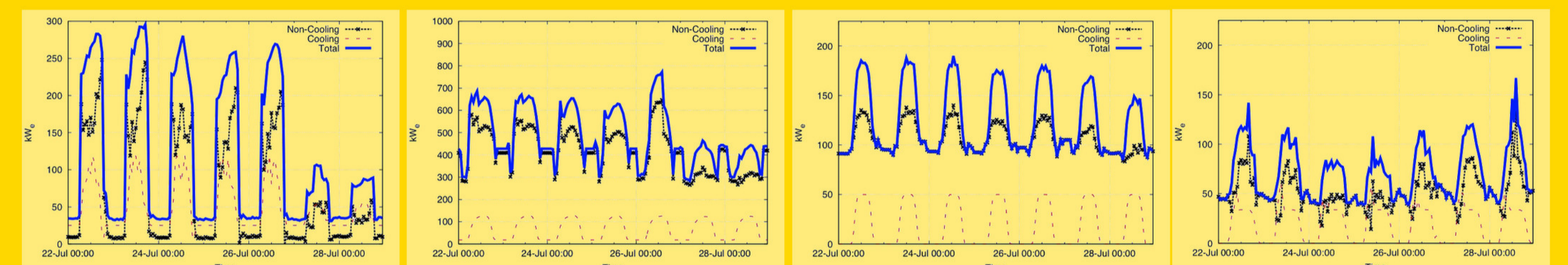


Model

Four facilities were considered in this study, representing a cross-section of buildings with associated DERs: a university building with solar-thermal-assisted HVAC, hot and cold TES, based on the Mechanical Engineering building at UNM; an office complex with a large PV array and sensible cold TES, based on the One Sun Plaza complex in Albuquerque; movie studios with large electric chillers and an array of ice storage tanks; a commercial building served by a microgrid, based on the Aperture Center at Mesa del Sol.

For the purposes of this study, these facilities, ranging in peak load from 120 kW to approximately 0.5 MW, were located virtually on the Studio 14 feeder at Mesa del Sol. Studio 14 has a nominal operating capacity of 5 MW, and also hosts a 0.5 MW distribution-level PV array with 1 MWh battery storage.

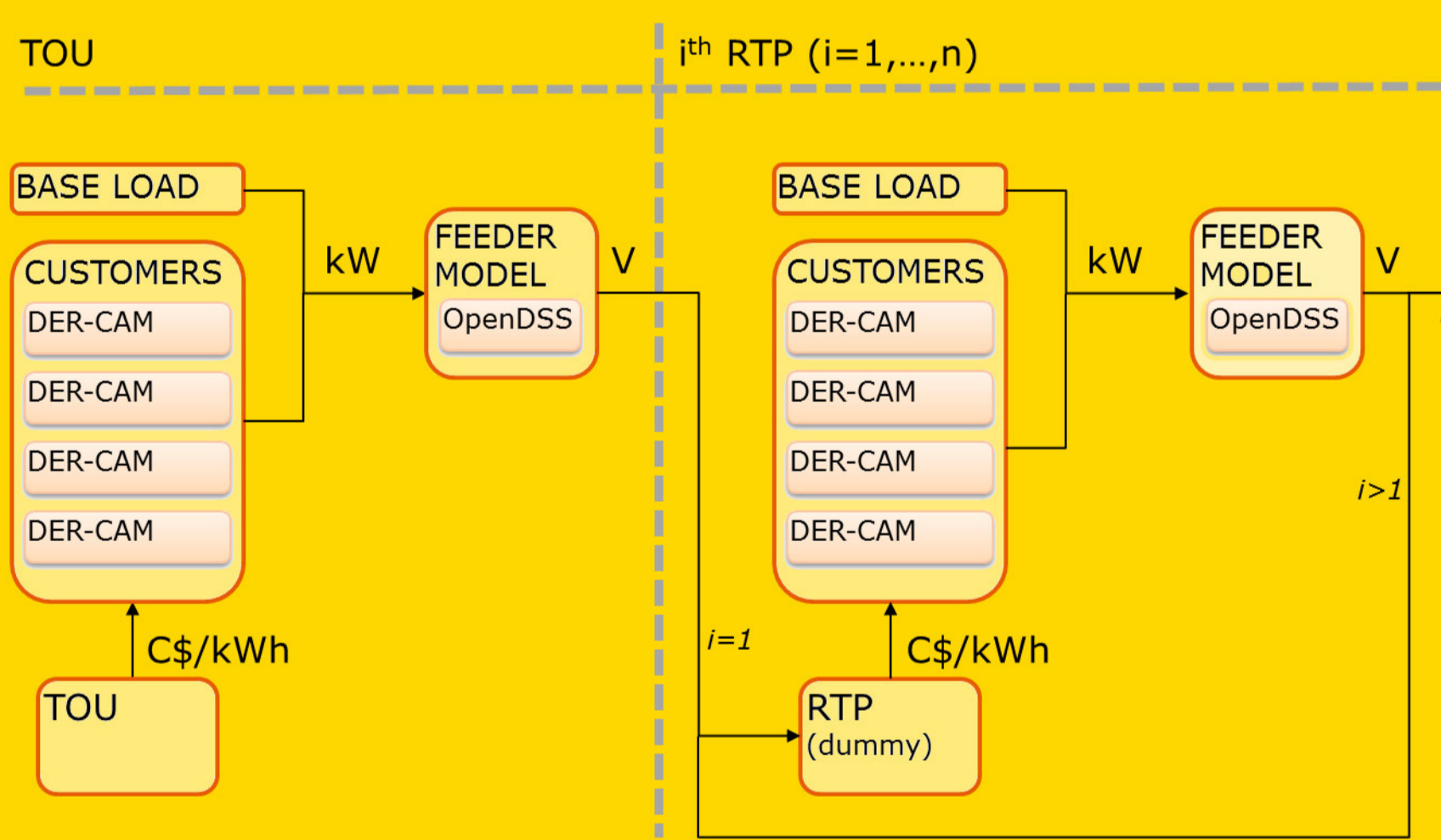
The electric and thermal loads of the buildings were characterized based on historical data and from building energy models (TRNSYS). Performance parameters of the DER technology in each facility was used to build DER-CAM models of each facility. Based on these models and loads, and on weather data, DER-CAM was used to produce optimized schedules for each facility.



The Studio 14 feeder was modeled in detail using OpenDSS, a distribution system simulator developed by the Electric Power Research Institute. The four schedulable facilities were connected electrically to the Studio 14 feeder, in addition to a background load obtained from data provided by the utility. The outputs of the simulation include voltage, current, power, phase at any location on the feeder. Voltage at one of the nodes was used here as an indicator of power quality.

Methods

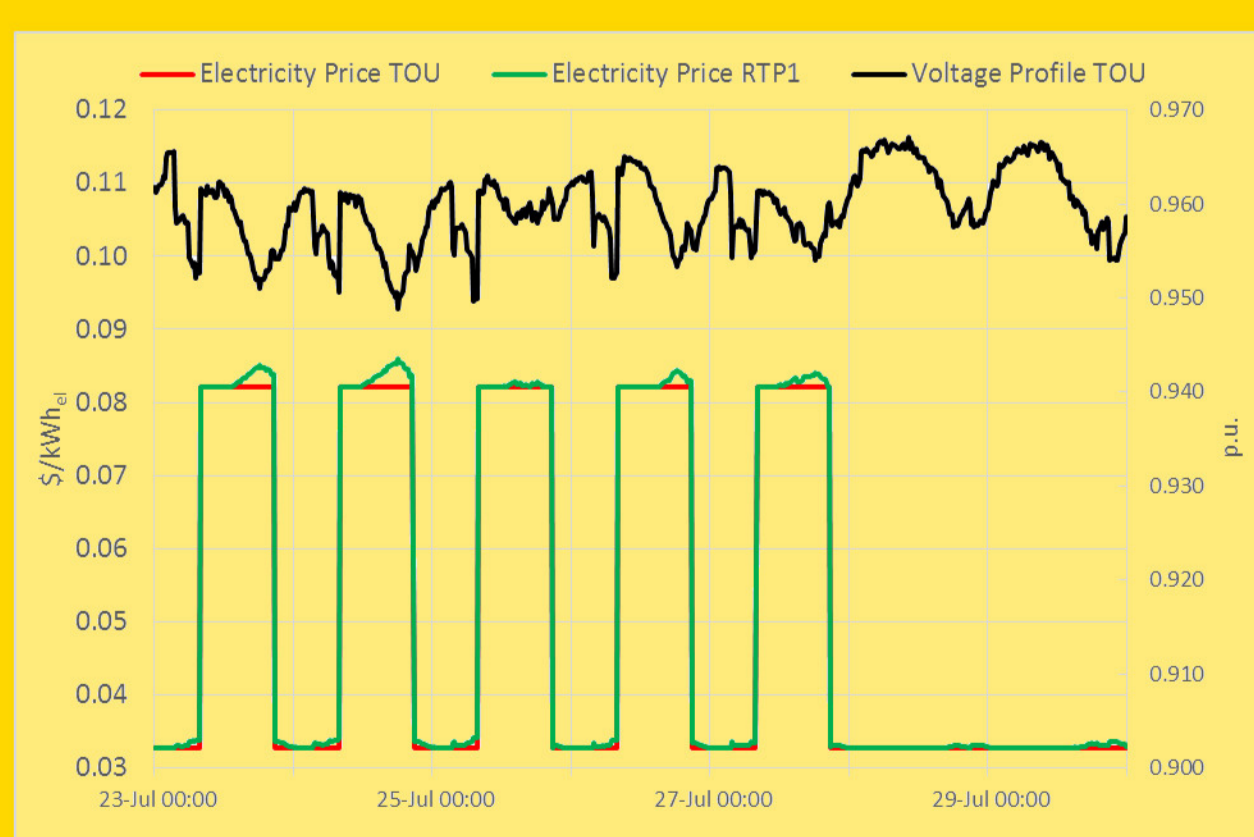
To prevent undesirable collective consequences on the feeder resulting from the individual optimizations, a cost can be associated with certain power flow variables predicted by the OpenDSS simulation. This represents a "local distribution cost" that can be added to the original electricity tariff. This way, excess loads or voltage drops originating from, say, simultaneous activation of energy storage devices at the onset of the "off-peak" part of the tariff can be corrected during a second or further iteration of the optimization process.



$$RTP_i(t) = \begin{cases} RTP_{i-1}(t) & \text{if } V_{i-1}(t) < V_{ref} \\ RTP_{i-1}(t) & \text{otherwise} \end{cases}$$

The iterative scheme used here progressively incorporates the collective effects of individual "greedy" optimizations. The simple form of the RTP also retains memory from previous iterations to maintain stability.

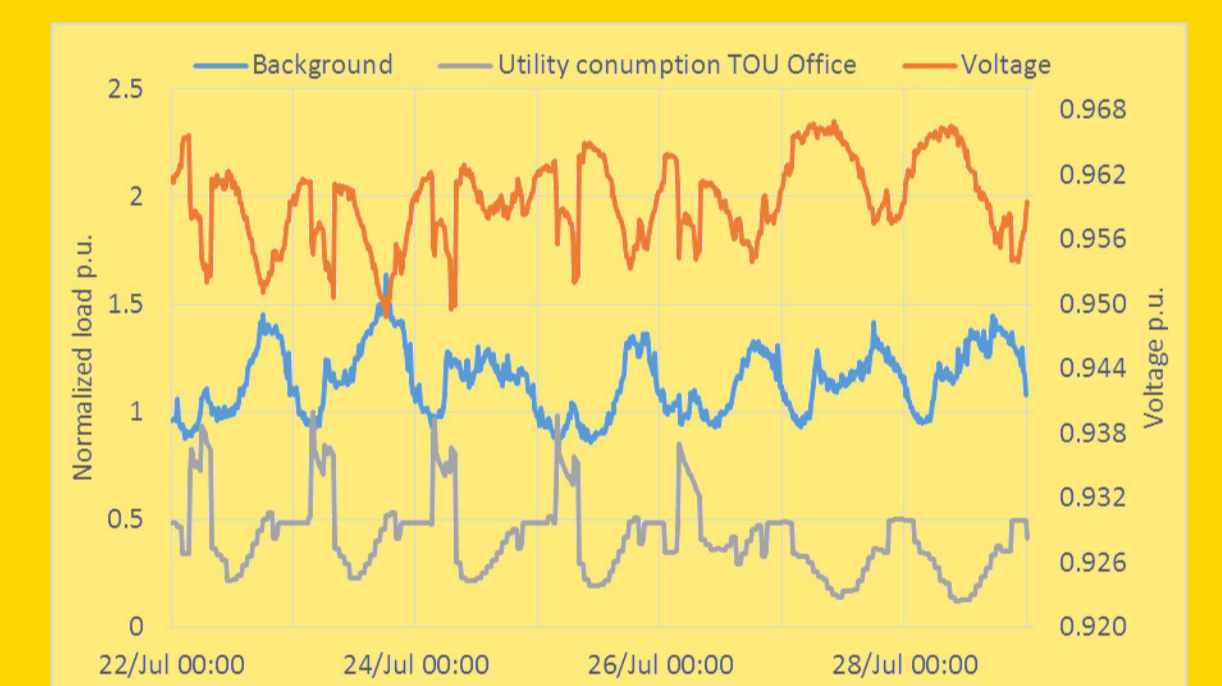
The voltage at one of the more sensitive nodes, co-located with One Sun Plaza, is used in this study, for the sake of simplicity.



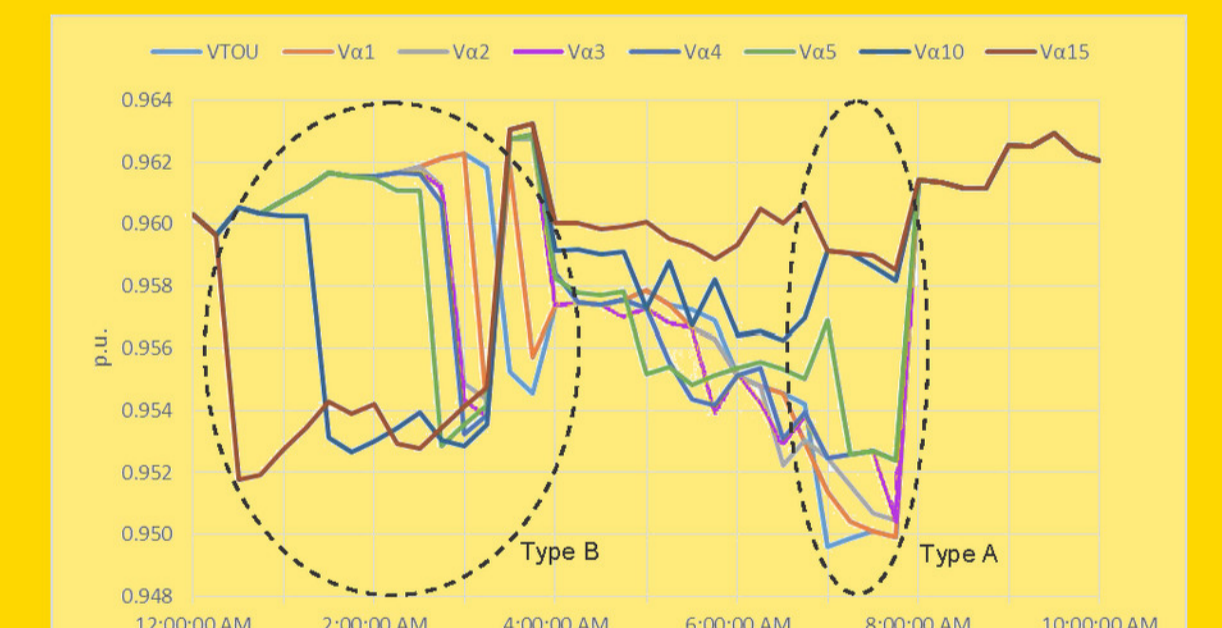
New Mexico has a simple time of use (TOU) tariff, designed to encourage off-peak consumption at the system level. This cannot account for distribution-level effects of DER optimization. The pseudo-RTP that is used by the DER-CAM optimization is in the form of small corrections to the TOU tariff. The pseudo-RTP could just as easily be applied to more complex tariffs, such as actual RTP schemes.

Results

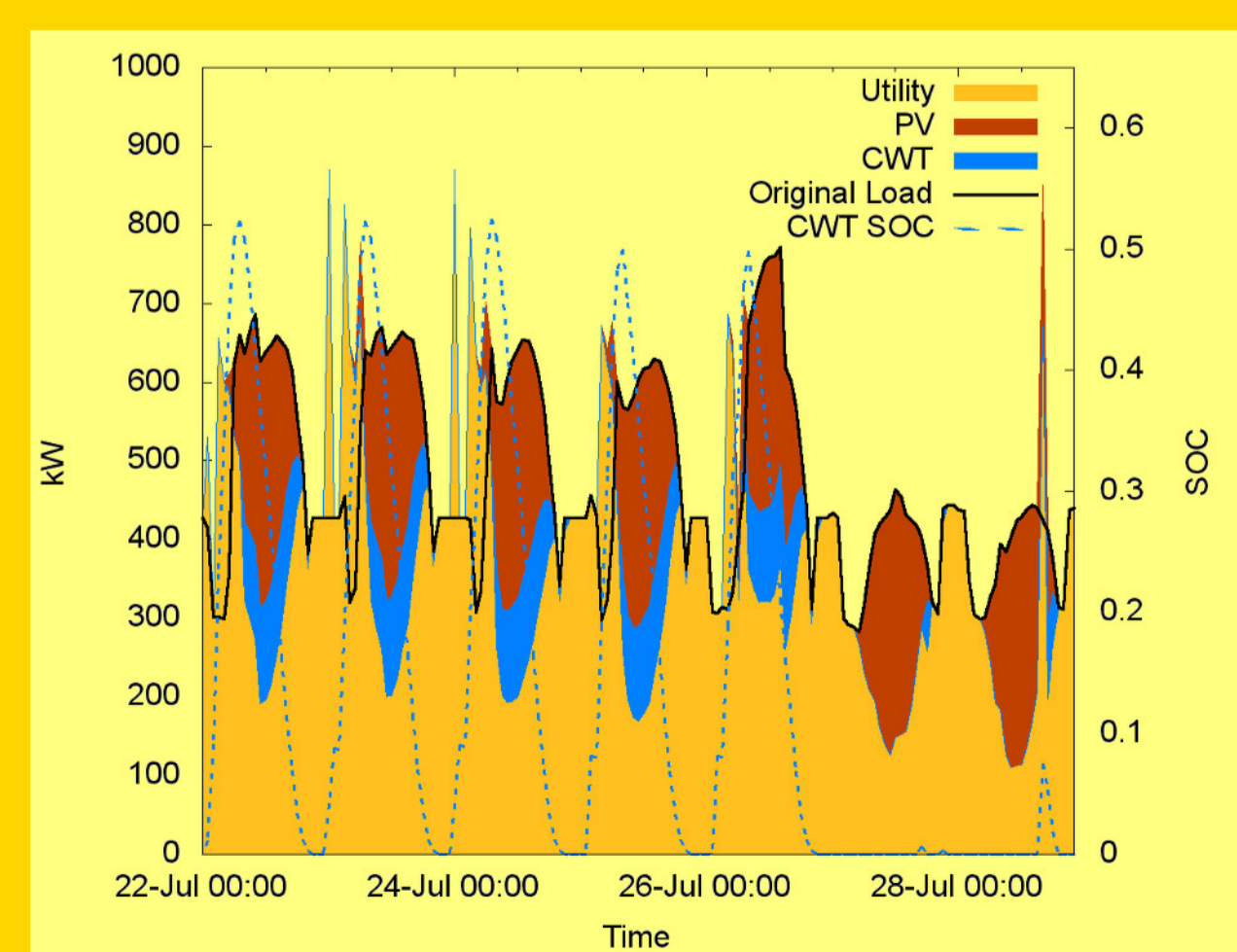
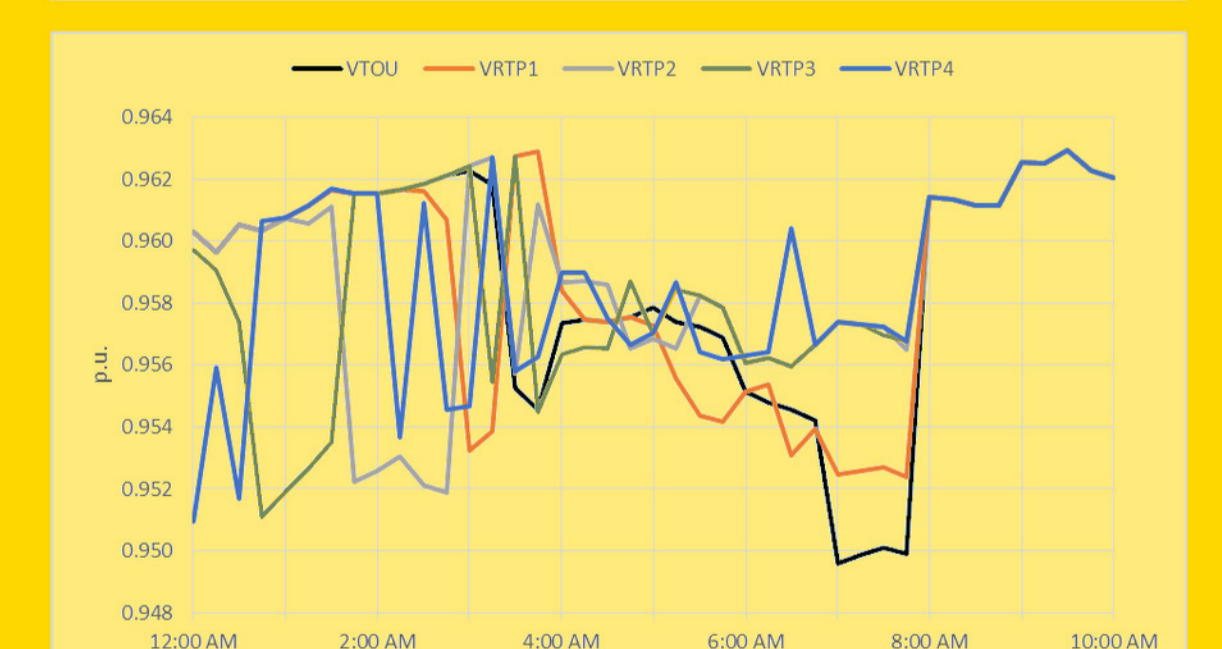
The voltage history at the One Sun Plaza facility shows the effect of local vs. background loads. Drops in voltage are observed when the large chillers are activated to charge the cold TES. In standalone optimization, this occurs just before the onset of the "on peak" tariff, to minimize storage losses. Voltage drops also occur in the afternoon, coinciding with the system peak. These are more difficult to address locally.



The sensitivity of the voltage drop on the value of the nonlinearity parameter α is apparent from the comparison of voltage time histories. Voltage disturbances of "type A" are reduced by increased nonlinearity, at the expense of smaller shifted "type B" disturbances resulting from the modified charging periods. The optimal compromise appears to be $\alpha = 4$.

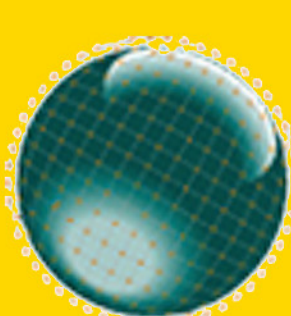


As with most iterative solution techniques, the solution improves with number of iterations. Convergence of the reduction of the "type A" disturbance is rapid. Smaller disturbances of "type B" with increasing time shifts result from successive iterations, indicating that stabilizing techniques (e.g. relaxation) may be desirable.



The effect of the coordinated optimization is clearly visible at the local level. The peak load at the One sun Plaza facility decreases from almost 1 MW to less than 800 kW. Moreover, the peak charging loads are more evenly distributed through time. The TES is completely discharged for shorter periods of time compared to the case for standalone optimization, possibly resulting in less optimal performance. However, increases in operating costs resulting from the collective optimization are found to be minimal, less than one percent.

We find that it is possible to improve power flow parameters in a high-DER distribution feeder by combining models of the DERs and associated facilities with an electrical model of the distribution feeder in the optimization process, via a pseudo-real-time price, at low computational overhead.



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