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Title: Resilient Off-grid Microgrids: Capacity Planning and N-1 Security

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# Resilient Off-grid Microgrids: Capacity Planning and N-1 Security

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Abstract: LA-UR-16-24708


## Abstract

Despite the long distance power transmission capabilities, there are some remote communities in Alaska and Hawaii that are not connected to these systems. These communities rely on small, disconnected distribution systems, i.e., microgrids to deliver power. More importantly, perhaps, there is a general trend to support microgrid development within large transmission systems for economic, environmental, and reliability reasons. However, microgrids are not held to same reliability standards as transmission grids and can place many communities at risk for extended black-outs. To address this issue, we develop an optimization model and algorithm for capacity planning and operations of microgrids that includes N-1 security and other modeling features. The effectiveness of the approach is demonstrated using the IEEE 13 node test feeder and a model of the Nome, Alaska distribution system.


## Off-grid Microgrids

A network of distributed energy resources (DER) that consist of small power generating devices like diesel generators, small hydro-electric power stations, wind turbines and/or power storing devices (e.g. batteries) that supply and store power to remote communities and are not connected to the national grid are known as **off-grid microgrids**.


Source: http://energy.gildemeister.com/en/utilise/off-gridsolutions

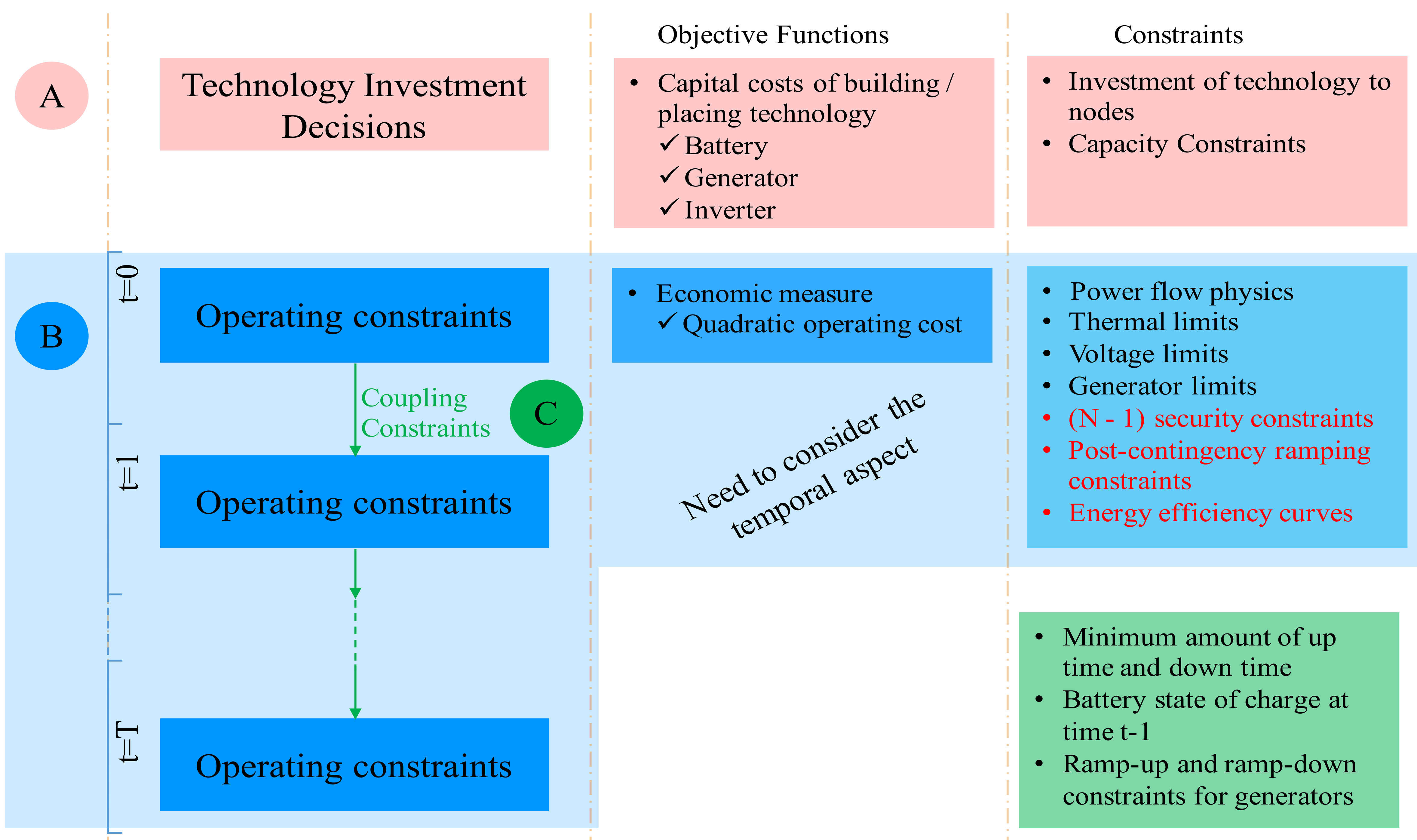
## Research Methods

- Formulate matahematical formulation for planning and operation of remote offgrid microgrids
- Develop relaxations, approximations and algorithms to solve problem faster
- Test the model on standard IEEE-13 node test feeder
- Implement the model on a real network

## References


- Baran, Mesut E., and Felix F. Wu. 'Network reconfiguration in distribution systems for loss reduction and load balancing.' IEEE Transactions on Power Delivery 4.2 (1989): 1401-1407.
- Waltz, R., and T. D. Plantenga. 'KNITRO User's Manual Version 6, Ziena Optimization.' (2009).
- Kersting, William H. 'Radial distribution test feeders.' Power Engineering Society Winter Meeting, 2001. IEEE. Vol. 2. IEEE, 2001.


## Problem Description



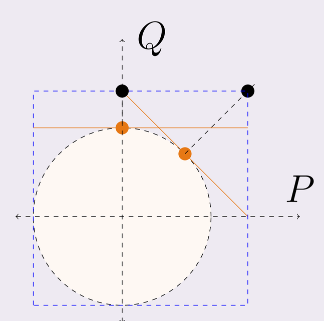

## Relaxation, Approximation and Algorithm

### Thermal Limit Constraints

$f(P,Q) = (P_{ij,t})^2 + (Q_{ij,t})^2 - (\tilde{T}_{ij})^2 \leq 0 \; \forall \; ij \in \mathcal{E}, t \in T$

The above quadratic constraints are applied in a lazy fashion using Lazy Callbacks

**Lazy Cuts**




for all solver iterations, $i$, with value $P_i$ and $Q_i$

if $\frac{f(P_i,Q_i)}{(\tilde{T}_i)^2} \geq$ tolerance

$f(P_i,Q_i) + (P - P_i)(f'(P_i)) + (Q - Q_i)(f'(Q_i)) = 0$

end if

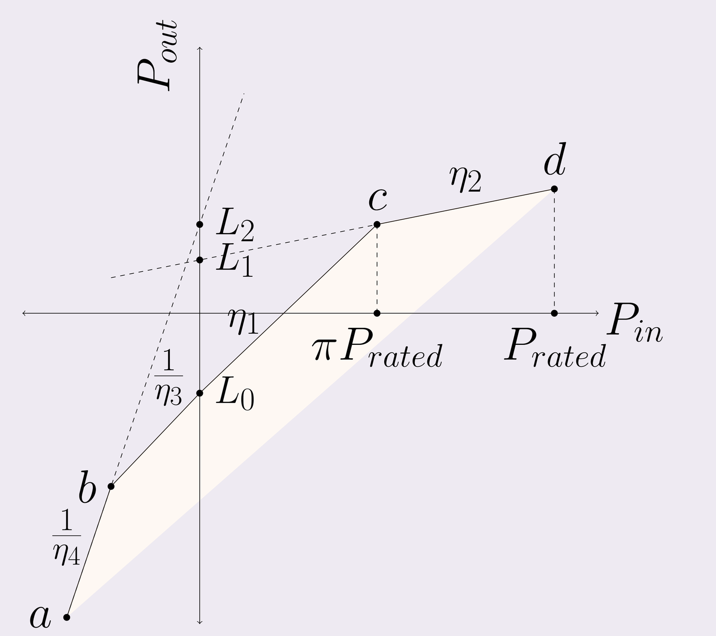
end

### Piecewise Linearization for Efficiency Curves

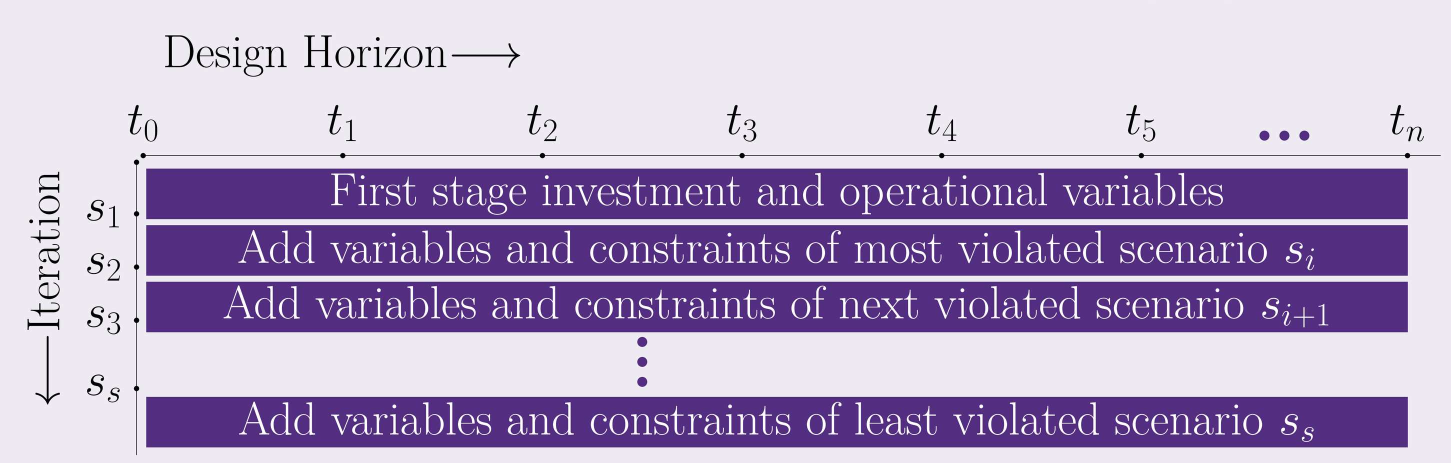
for all $k \in$ number of pieces

$P_{\text{out}} \leq f_k(P_{\text{in}}, L_0)$

end

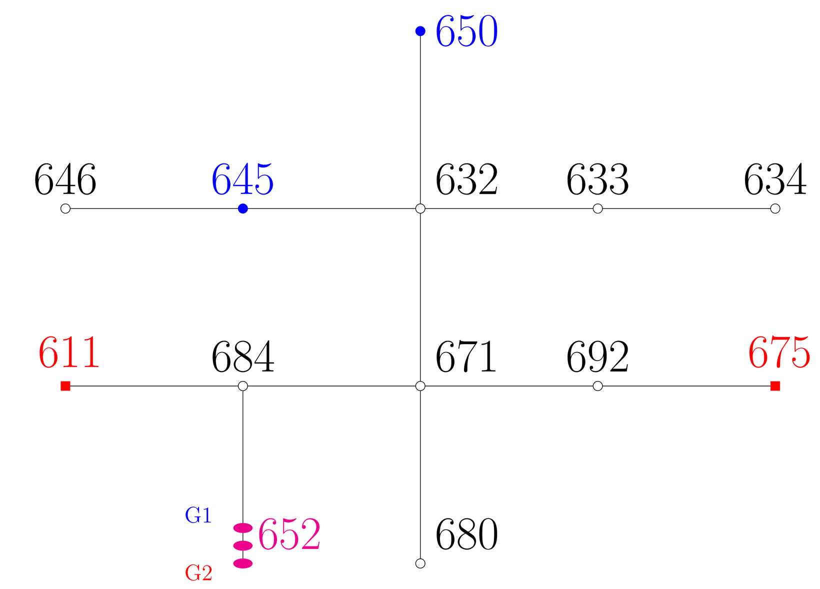



Schematic Representation of Scenario Based Decomposition (SBD)

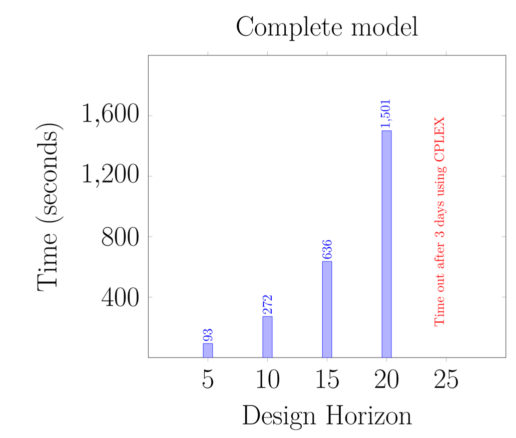


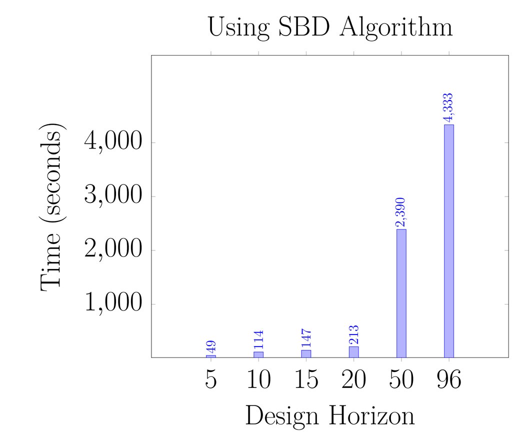

## Results

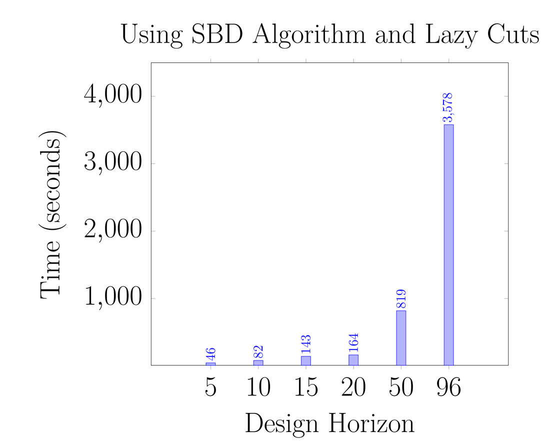
- Tested using IEEE 13 node test feeder
- With contingency, an extra generator is installed at node 652
- SBD using Lazy callback seems to be an efficient algorithm

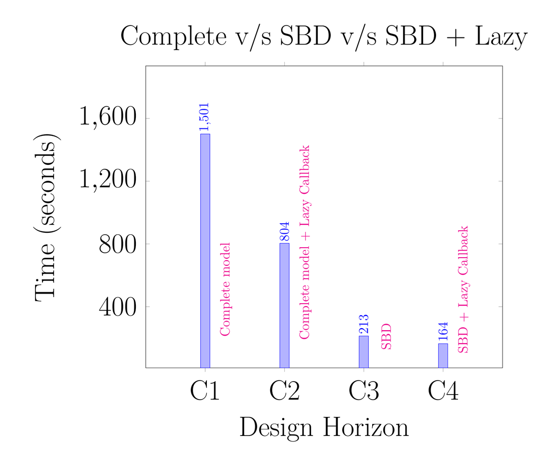



### Solution Time

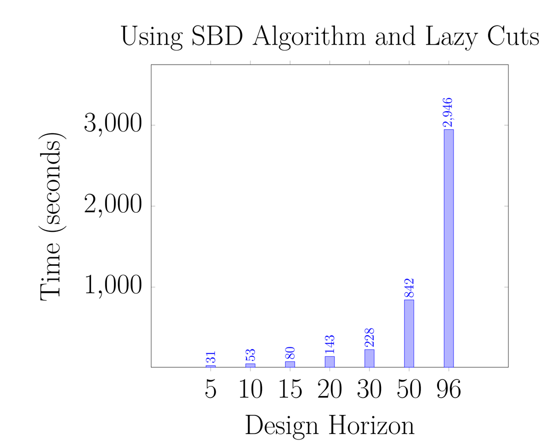


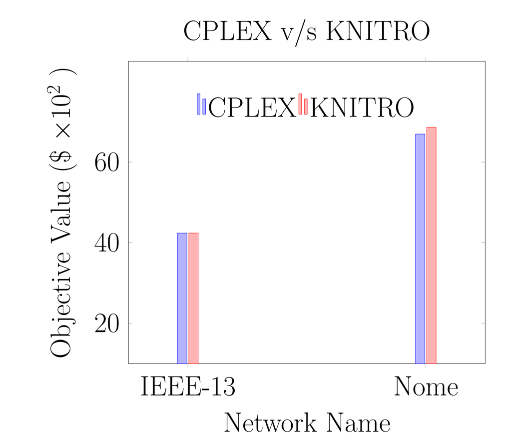




### Alaskan Microgrids Solution




### *Distflow v/s LinDistflow*




## Future Work

- To solve multiple days problem
  - Implement receding horizon
  - Implement fixed boundary conditions
  - Enhance using benders decomposition
- Consider uncertainty in wind speed and irradiance
- Enhance model to include network topology design

## Affiliations

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