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Sandia National Laboratories

Investment Optimization to Improve Power Distribution System Reliability Metrics

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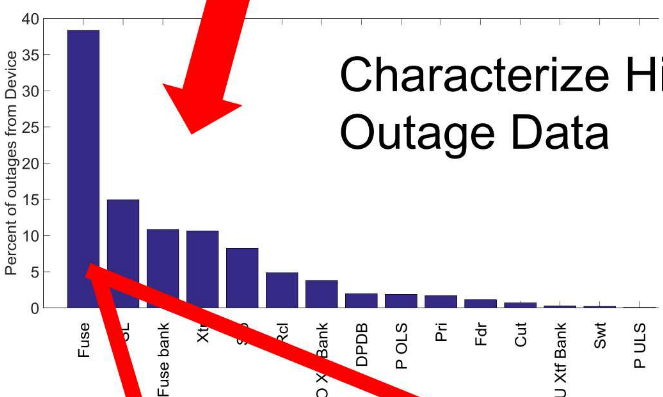
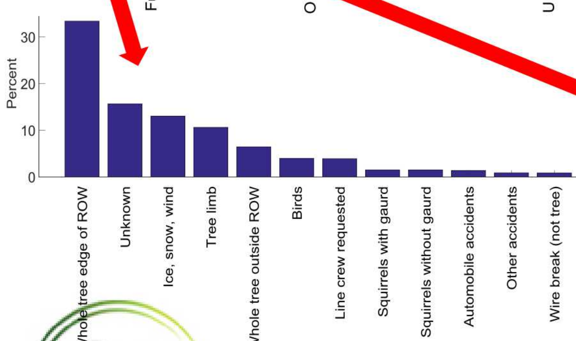
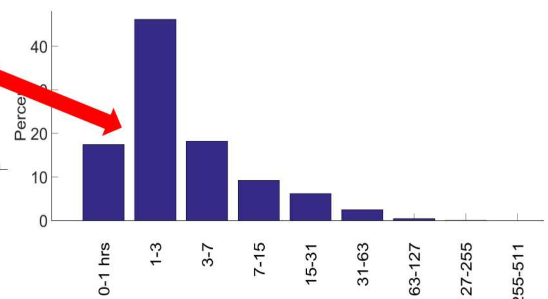
Inputs to Optimization Model to Determine Optimal Investments

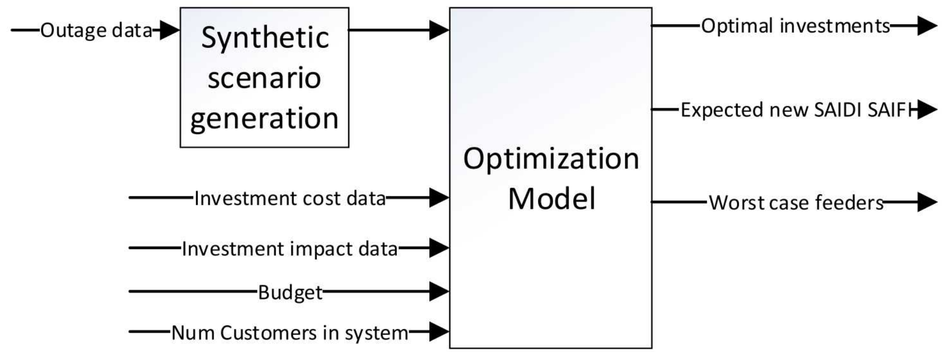
Feeder ID	Device	Cause	Duration (min)	Number of Customers
1	Single line outage (Slo)	UNKNOWN IN ICE, SNOW, WIND, ELEC STORM	117	5
3	Fuse	WHOLE TREE FAILURE EDGE OF ROW	56	42
5	Fuse	TREE LIMB	1467	237



Characterize Historical Outage Data







Sample historical outage probability density functions to create synthetic data sets representing a future year scenario

Optimization Model

Nonlinear mixed integer program

$$minimize \frac{\text{SAIDI}_{up}}{\text{SAIDI}_{syn}} + \frac{\text{SAIFI}_{up}}{\text{SAIFI}_{syn}}$$

$$\sum_{i,d,u \in U_{i,d}} c_u y_{i,d,u} \leq B$$

$$SAIDI_{up} = \frac{1}{N} \sum_{o \in O} CO_o TO_o$$

$$SAIFI_{up} = \frac{1}{N} \sum_{o \in O} CO_o$$

$$CO_o = \min_{u \in U_o} \{ C_{o,u} y_{i_o,d_o,u} + C_o (1 - y_{i_o,d_o,u}) \} \quad \forall o \in O$$

$$TO_o = \min_{u \in U_o} \{ T_{o,u} y_{i_o,d_o,u} + T_o (1 - y_{i_o,d_o,u}) \} \quad \forall o \in O$$

Additional constraints to linearize the model

$$CO_o \leq C_{o,u} y_{i_o,d_o,u} + C_o (1 - y_{i_o,d_o,u}) \quad \forall o \in O, u \in U_o$$

$$CO_o \geq C_{o,u} [y_{i_o,d_o,u} + C_o (1 - y_{i_o,d_o,u})] m_{o,u} \; \forall o \in O, u \in U_o$$

$$\sum_{u \in U_o} m_{o,u} = 1 \quad \forall o \in O$$

$$TO_o \leq T_{o,u} y_{i_o,d_o,u} + T_o (1 - y_{i_o,d_o,u}) \quad \forall o \in O, u \in V_o$$

$$TO_o \geq T_{o,u} [y_{i_o,d_o,u} + T_o (1 - y_{i_o,d_o,u})] n_{o,u}$$

$$\sum_{u \in V_o} n_{o,u} = 1 \quad \forall o \in O$$

$$my_{o,u} \leq m_{o,u} \quad \forall o \in O, u \in U_o$$

$$my_{o,u} \leq y_{i_o,d_o,u} \quad \forall o \in O, u \in U_o$$

$$my_{o,u} \geq m_{o,u} + y_{i_o,d_o,u} + 1 \quad \forall o \in O, u \in U_o$$

$$ny_{o,u} \leq n_{o,u} \quad \forall o \in O, u \in V_o$$

$$ny_{o,u} \leq y_{i_o,d_o,u} \quad \forall o \in O, u \in V_o$$

$$ny_{o,u} \geq n_{o,u} + y_{i_o,d_o,u} + 1 \quad \forall o \in O, u \in V_o$$

$$COTO_o = \sum_{u \in U_o} \sum_{u' \in V_o} C_{o,u} T_{o,u'} m_{o,u} n_{o,u'} \quad \forall o \in O$$

$$mn_{o,u,u'} \leq m_{o,u} \quad \forall o \in O, u \in U_o, u' \in V_o$$

$$mn_{o,u,u'} \leq n_{o,u'} \quad \forall o \in O, u \in U_o, u' \in V_o$$

$$mn_{o,u,u'} \geq m_{o,u} + n_{o,u'} + 1 \quad \forall o \in O, u \in U_o, u' \in V_o$$

Also looking at using a dynamic programming algorithm to solve the problem

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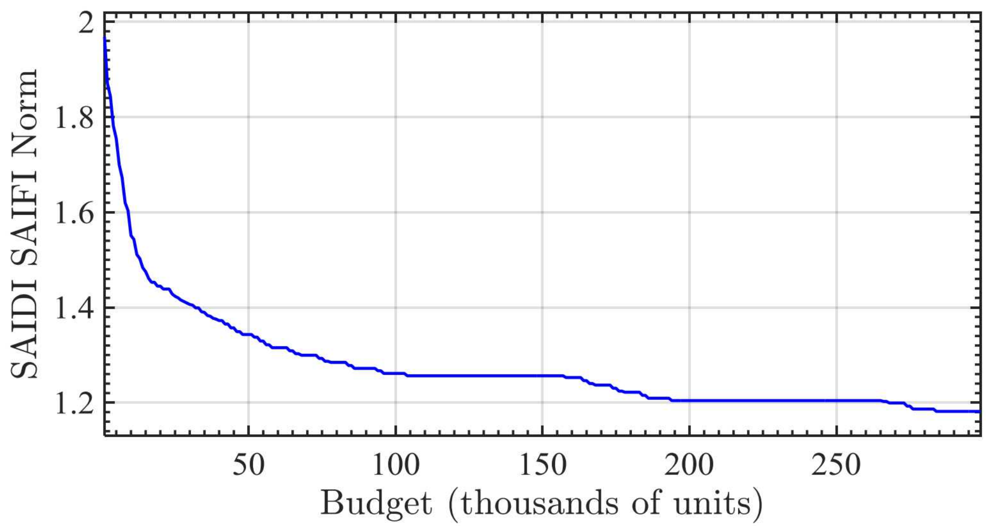
Conclusions

- The results indicate you can determine the optimal investments and significantly decrease reliability metrics.



Continuation work on a co-optimization to improve reliability metrics and power system resilience