Post-storm repair crew dispatch for distribution grid restoration using stochastic Monte Carlo tree search and deep neural networks

Hang Shuai[1], Fangxing Li[1] , Buxin She[1] , Xiaofei Wang[1], and Jin Zhao[1]
[1] The University of Tennessee, Knoxville

Background

- The extreme weather (e.g. storms, etc.) has became the main cause of power outages.
- After storms passed through, utilities need to dispatch crews to repair the damaged devices as fast as possible.
- However, many distribution grids are not equipped with sensors that can precisely pinpoint the faults locations.
- Besides, optimally dispatching crews to restore the system is a stochastic nonlinear problem which is hard to solve.

Fig. 1. Distribution system repair.

Deep reinforcement learning based distribution grid restoration strategy after storms

The utility crew routing problem is modeled as a MDP (Markov Decision Process) problem, and we recursively solve the problem :

$$X_t^*(S_t) = \arg\min_{x_t \in \chi_t(S_t)} \left(C_t(S_t, x_t) + \min_{\pi} \mathbb{E}\left\{ \sum_{\tau=t+1}^{T} C_\tau(S_\tau, X_\tau^\pi(S_\tau)) | S_0 \right\} \right)$$

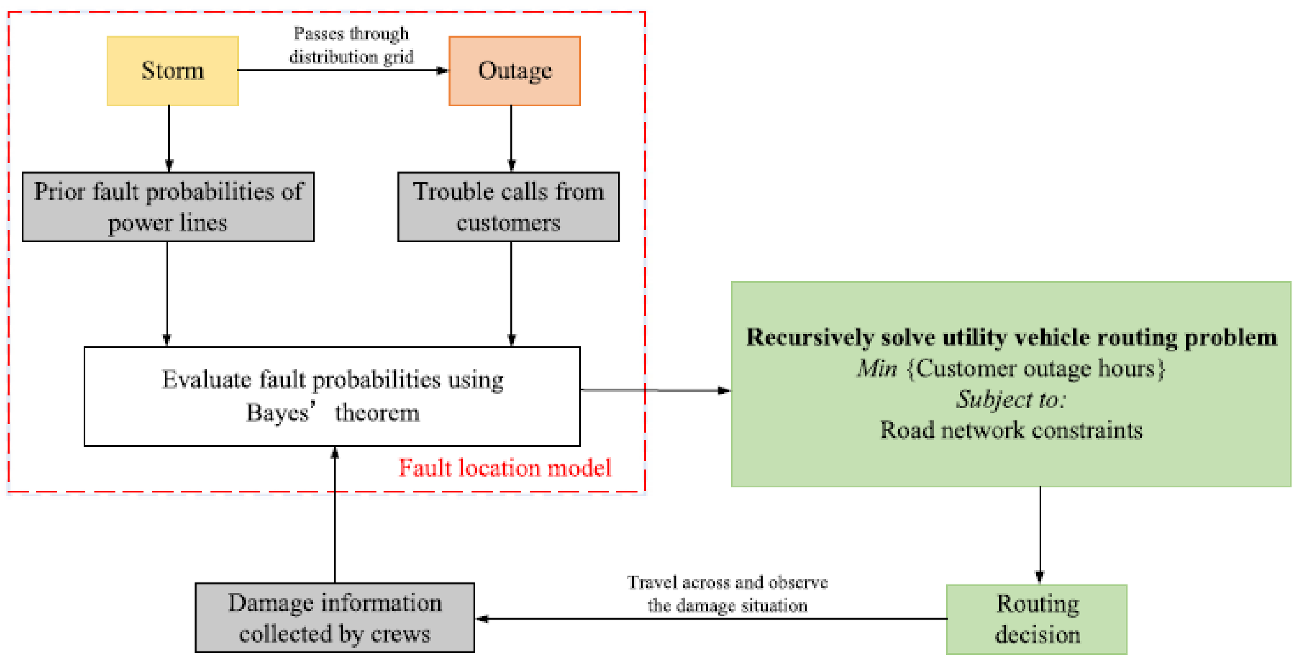

Fig. 2. Illustration of the post-storm UVR problem.

- Step1: Evaluate power line fault probabilities.
- Step 2: Get the routing decision using deep reinforcement learning method.

$$p(L^e_{t,j}=1|H_t,A_{t-1}) = \frac{\sum_{L^e_t \in \{\ell^e\}_{L^e_{t,j}=1}} p(H_t|L^e_t)p(L^e_t|A_{t-1},O_{t-1})}{\sum_{L^e_t \in \{\ell^e\}} p(H_t|L^e_t)p(L^e_t|A_{t-1},O_{t-1})}$$

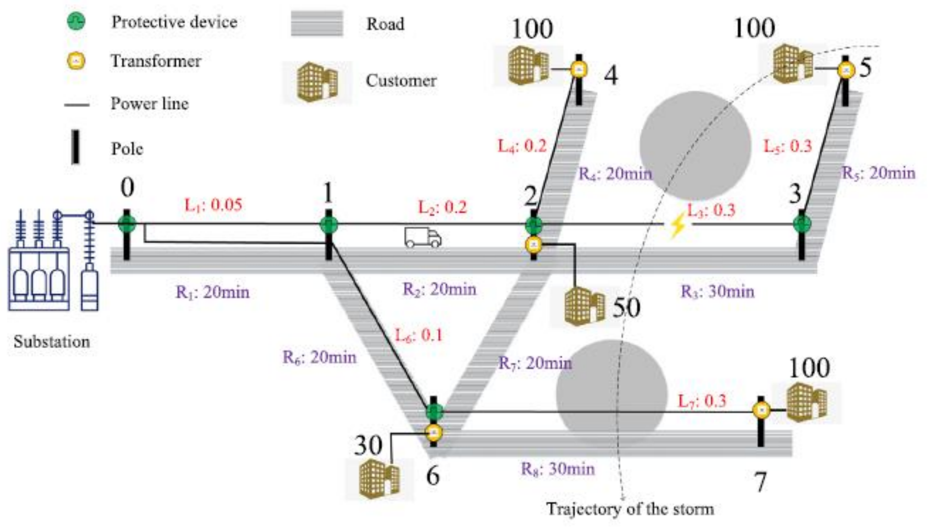

Fig. 3. Utility vehicle routing in a distribution system

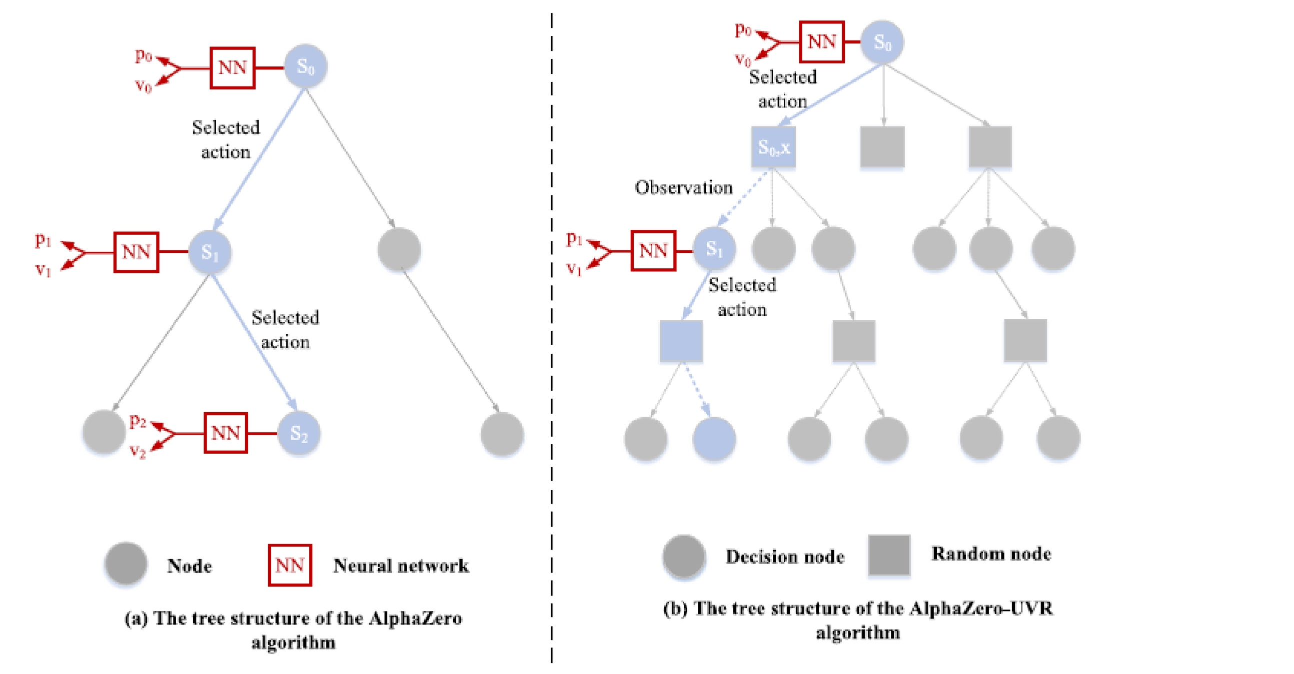

Fig. 4. Tree structure of the original AlphaZero algorithm [40] and the developed AlphaZero-UVR algorithm. The neural network takes system state as input and outputs action probabilities p with components $p_a = Pr(a|S)$ for each action a, and a scalar value v which represents the estimation of the expected outcome from the current state.

Case study

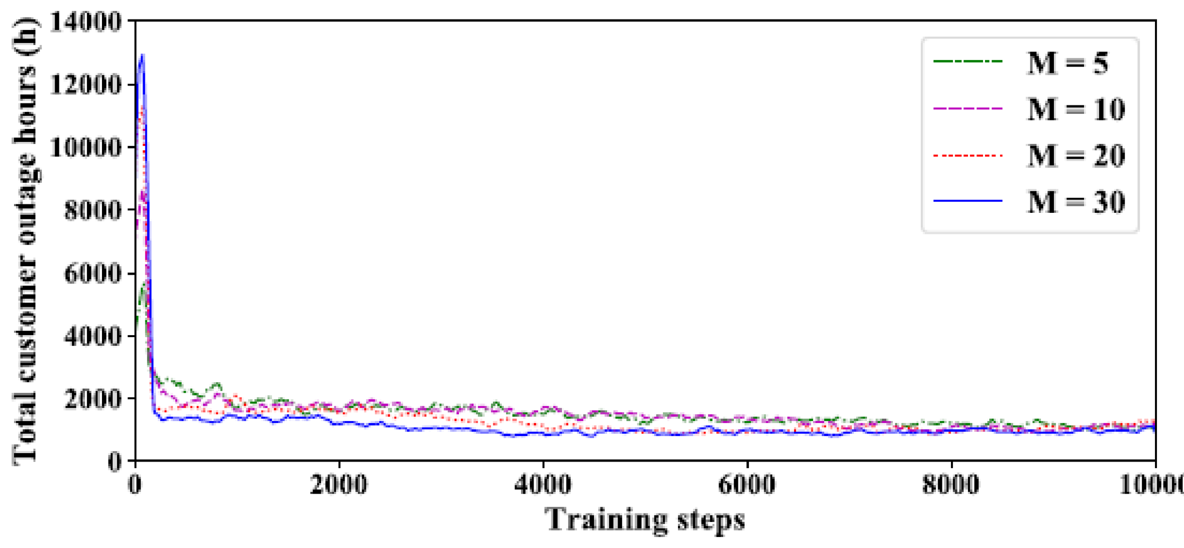

Fig. 5. The convergence process of the AlphaZero-UVR algorithm under different number of simulations per move.

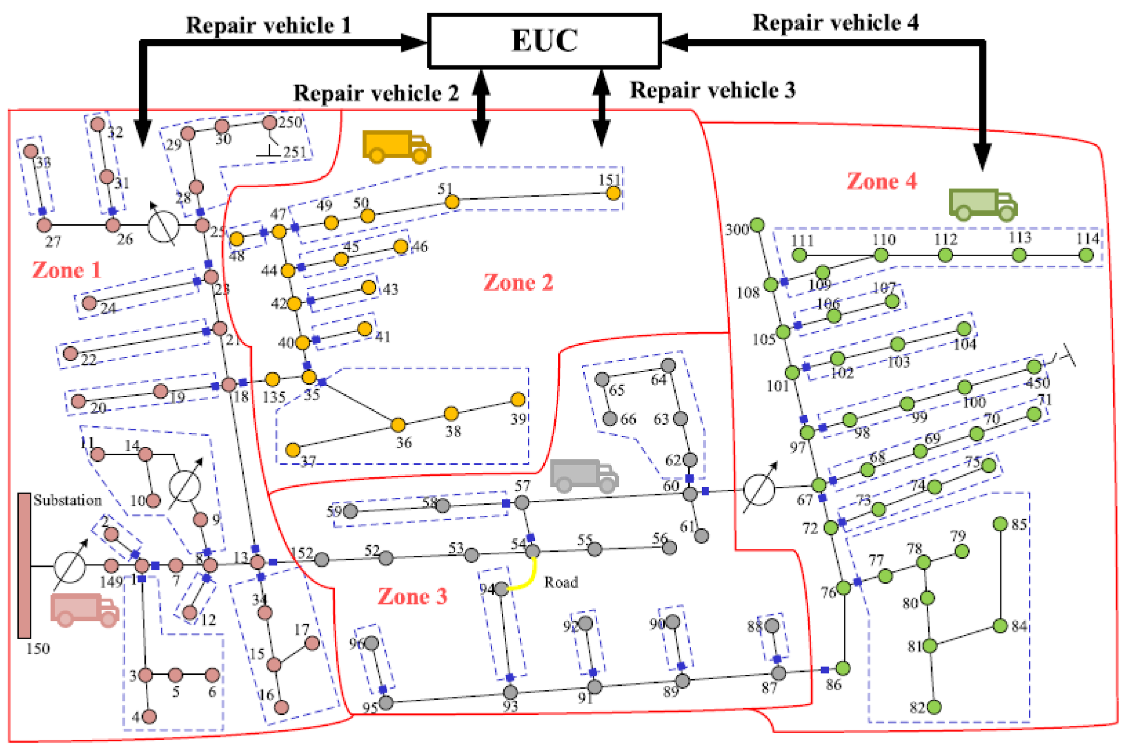

Fig. 7. The modified IEEE 123-node distribution system.

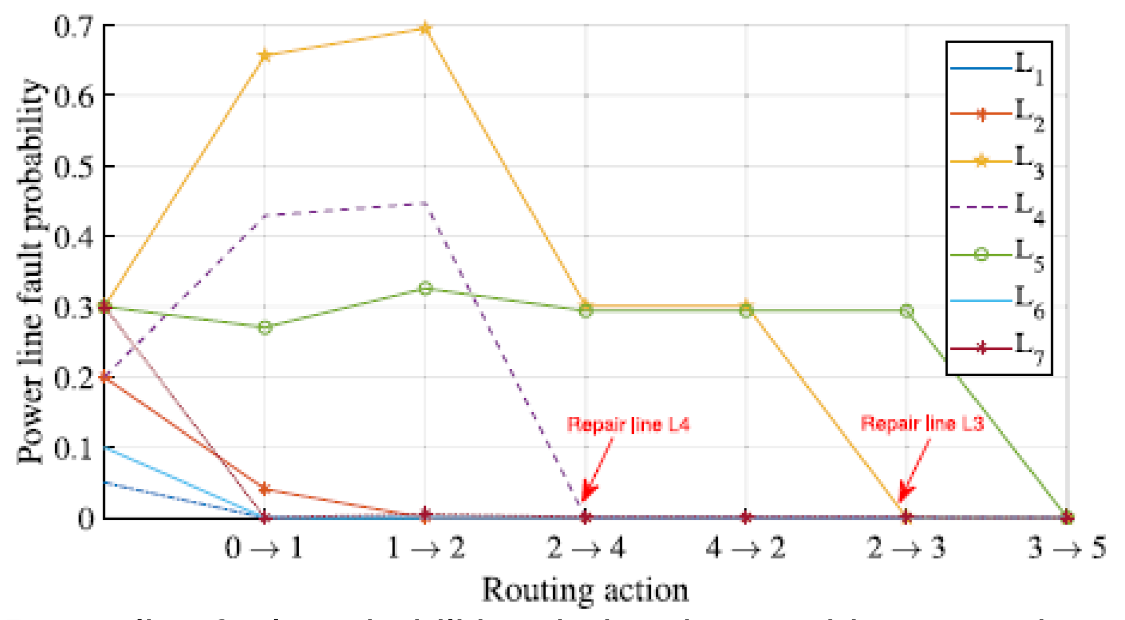

Fig. 6. Power line fault probabilities during the repairing procedure.

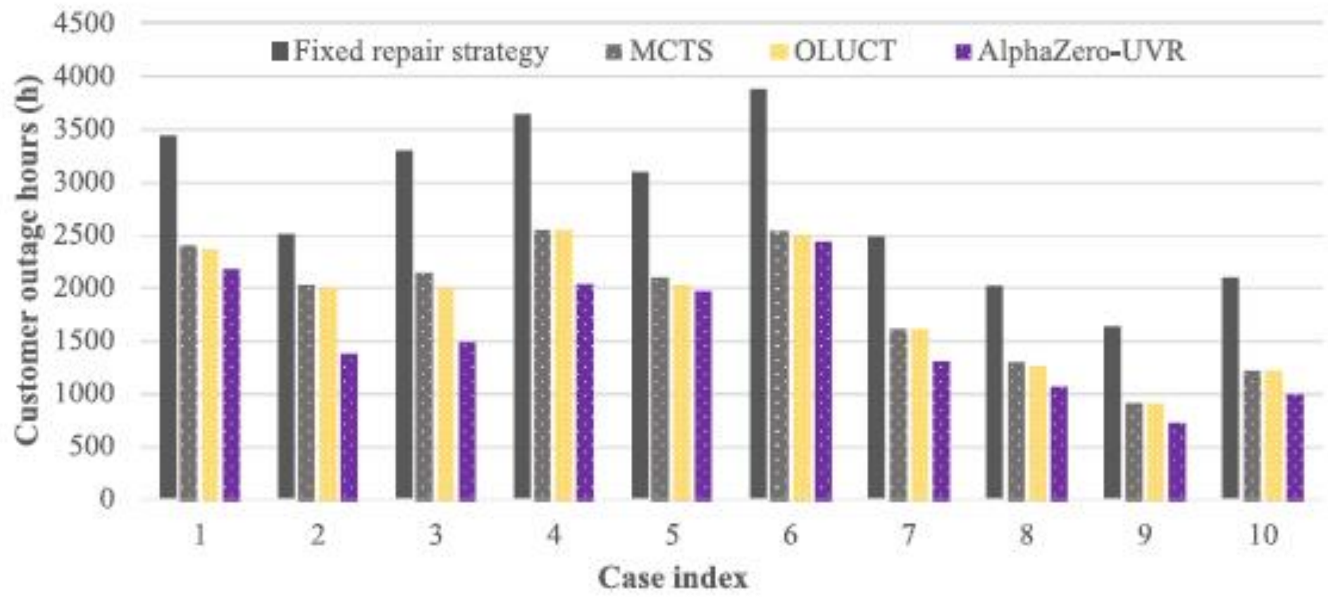

Fig. 8. The performance of the proposed algorithm and the comparing methods on the modified IEEE 123-node test system.

✓ Conclusion: The proposed AlphaZero-UVR algorithm performs better than traditional methods and MCTS-random (Monte Carlo tree search) algorithms