An Optimized Load Shedding Approach in Power Grids to Mitigate Cascading Failure

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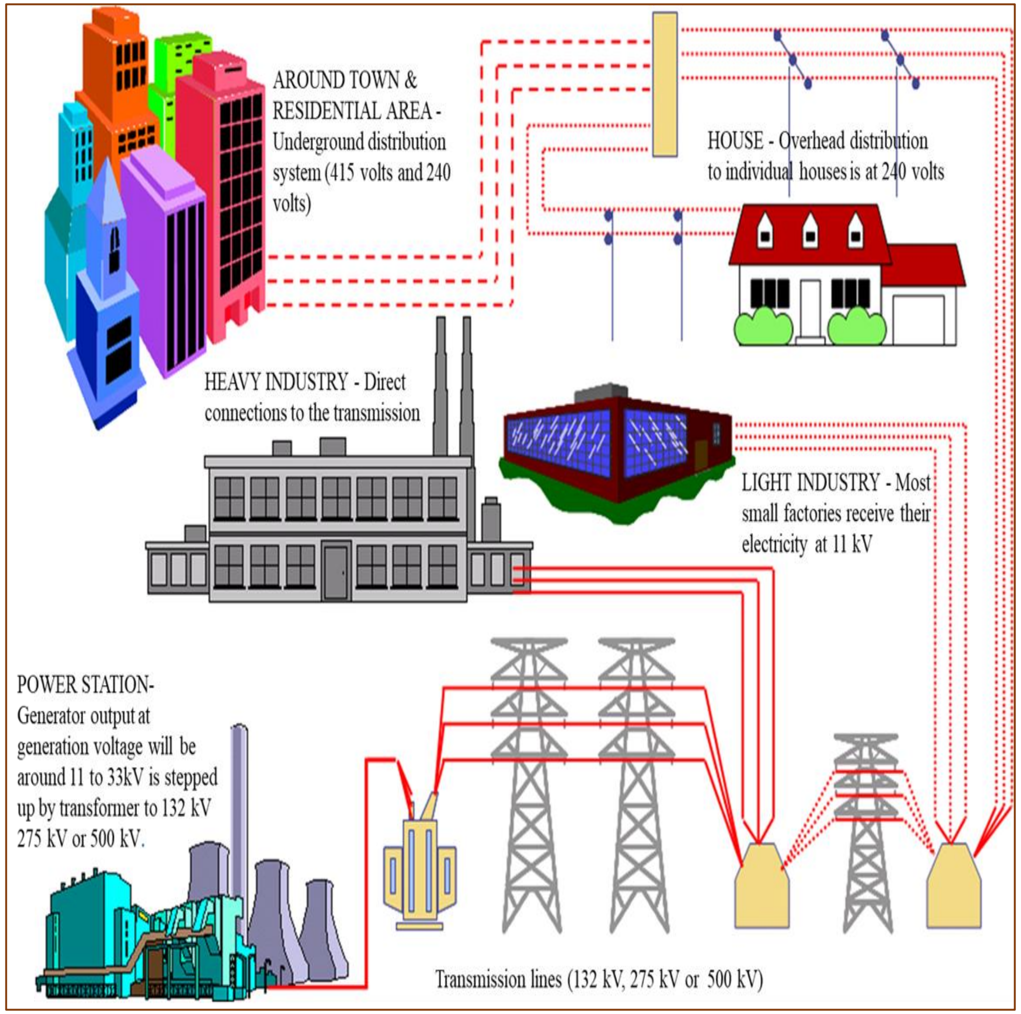
Introduction

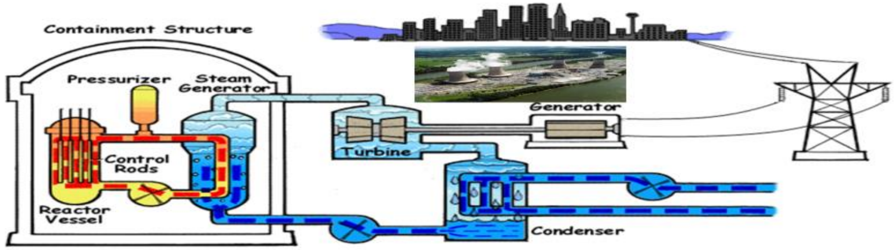
- Power grid security has always been a **key issue in power industry development**.
- The current operation of the power system is more complex due to the increase in **grid interconnection, electricity demand, and congestion in power exchanges**.
- The main significant challenge for grid operators is **maintaining a high security level in modern energy systems**.



Problem Definition

- The power grid collapses in previous years have **raised serious alarms about power system reliability and its ability to maintain a continuous power supply**, particularly to areas outside the fault zone during outages.

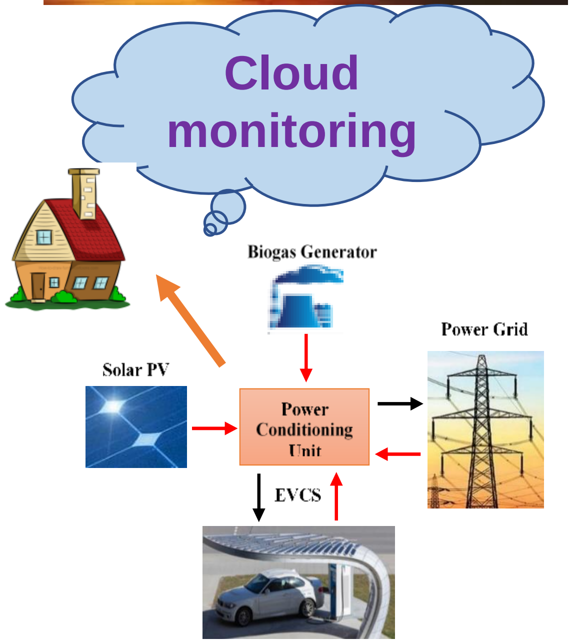
- In power system disruption events, power grid operators **must prioritize the safety of critical power network components and ensure the uninterrupted power supply to essential infrastructures** such as transportation and communication.



Related Studies

- Most studies mainly focus on **the amount of load shedding** and ignore the **location of load curtailment**, while others have not paid attention to **cloud computing**.

- There is a lack of **efficient algorithms to find the optimal load shedding location and the load amount to be removed** from the system during steady-state and transient conditions.



Main Objective

To develop an effective load shedding approach by implementing a hybrid algorithm for sizing and localizing the load curtailment in the power grid.

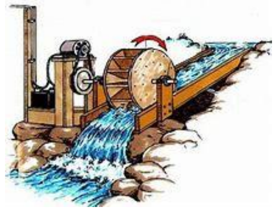
Leading to

Minimize

Problem Formulation

MINIMIZING

Through



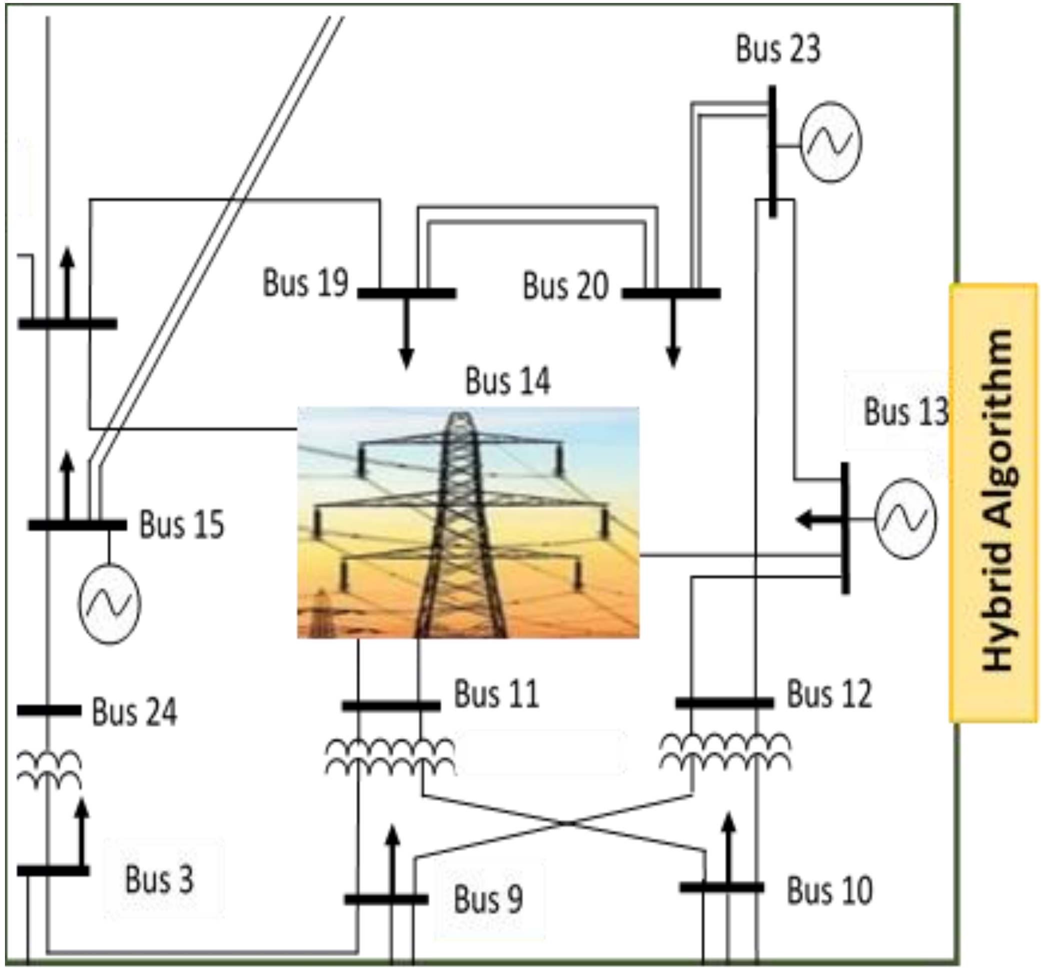
MAXIMIZE

Power Coordination
or
Load Shifting

MATHEMATICALLY

$$Minimize\ (S^{nor} - S^{abnor});\ where\ \begin{cases} f = f_o & ;\ (when\ P_{sup} \approx P_{\mathrm{dem}}) \\ v = v_0 & ;\ (when\ Q_{sup} \approx Q_{\mathrm{dem}}) \end{cases}$$

Hybrid Algorithm



(A) Steady state formulation (Load Flow)

(B) Application of PSO for load shedding

(C) Optimal load-shedding in cloud cnvironment

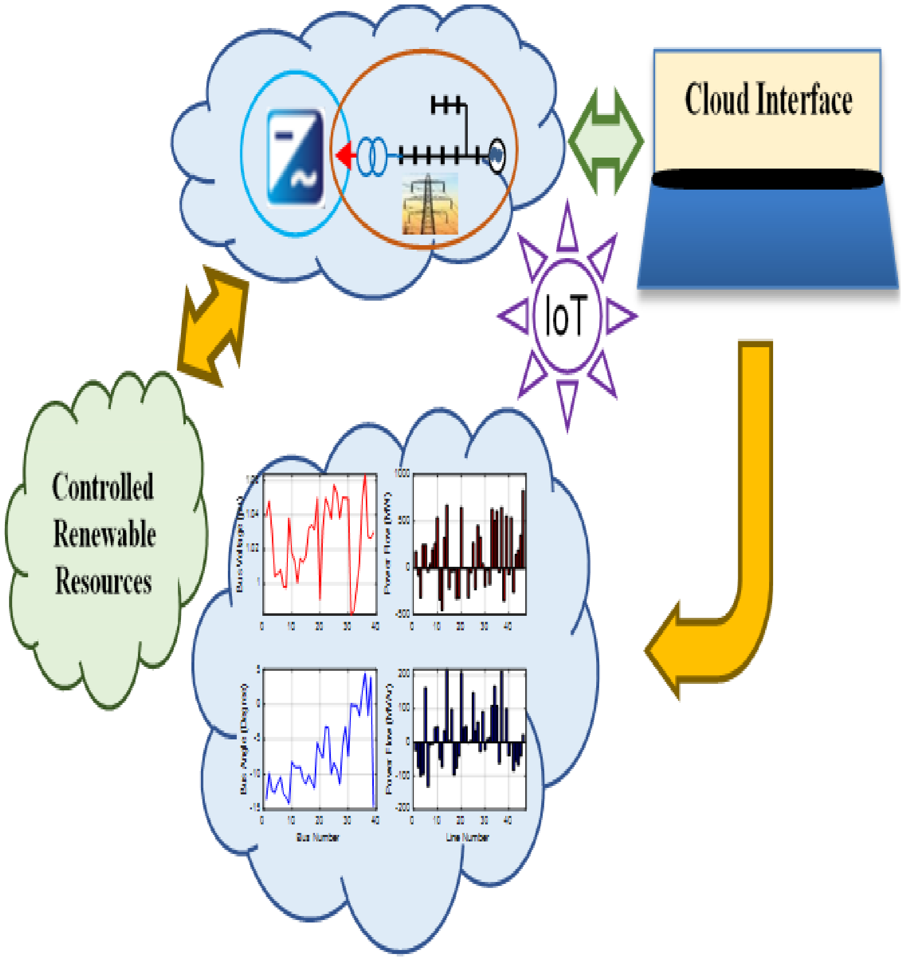
Application of Algorithm

In the first step, the mismatch equations (1) and (2) are solved using the Newton-Raphson power flow method to satisfy the power balance constraint at each bus (Power flow equations). This process is linked to data exported and imported from the cloud platform.

$$P - f_P(V, \delta) = 0$$

$$Q - f_Q(V, \delta) = 0$$

This step involves iteratively adjusting the voltage magnitudes and angles to minimize the power mismatch at each bus.



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The particle swarm optimization (PSO) algorithm, which draws inspiration from the foraging behavior of swarms of birds, is applied in this study. It can be summarized as follows:

- The output data from the previous step (load flow method) is used to examine the voltage limit for all buses and the total system loss.
- PSO minimizes the load curtailment by placing a dummy power plant at sensitive nodes associated with the large power loss.
- The power plants are represented as populations in the PSO algorithm. Each population has several individuals *xj (i)* randomly generated, with *j* being an indicator for each generator. The individuals are then used as particles of the algorithm.
- The replacement should be repeated until there is no more loss reduction, considering the voltage constraint is satisfied.

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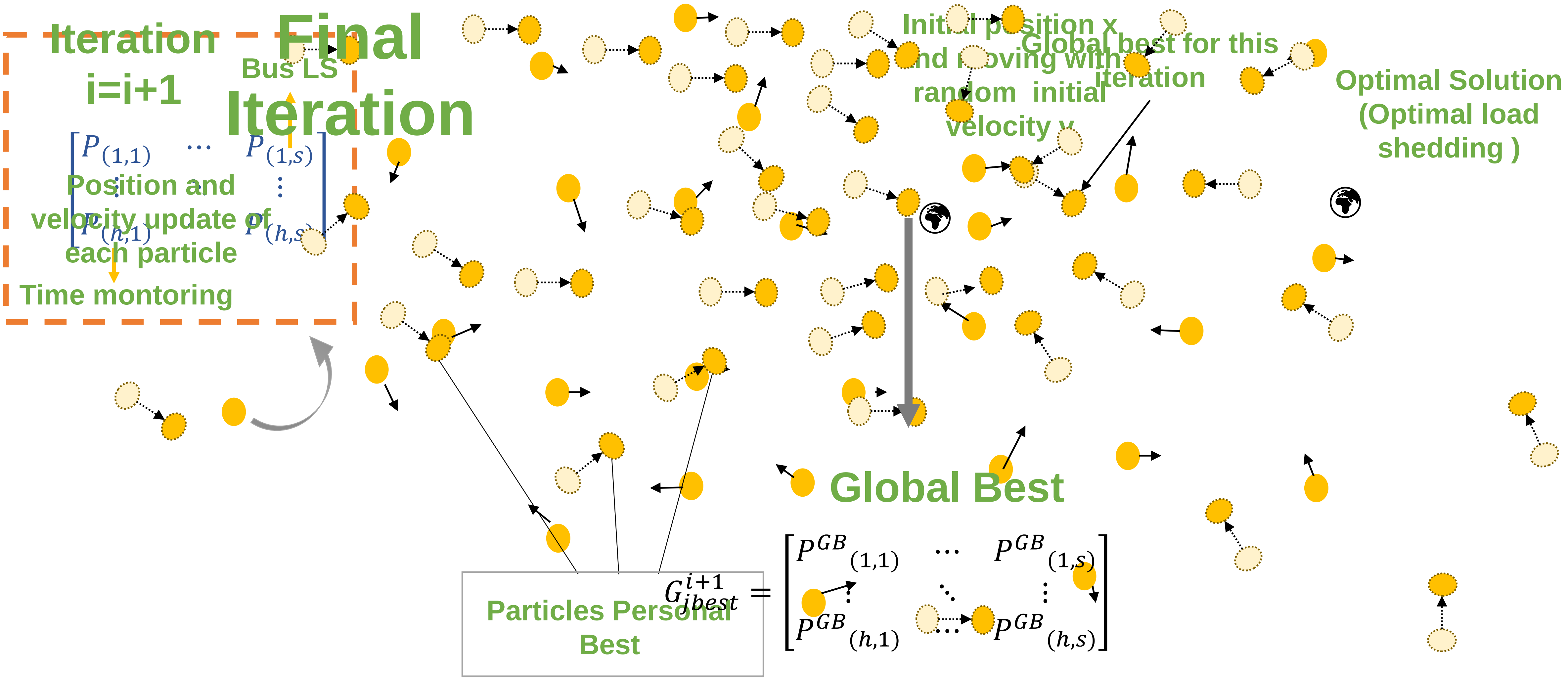
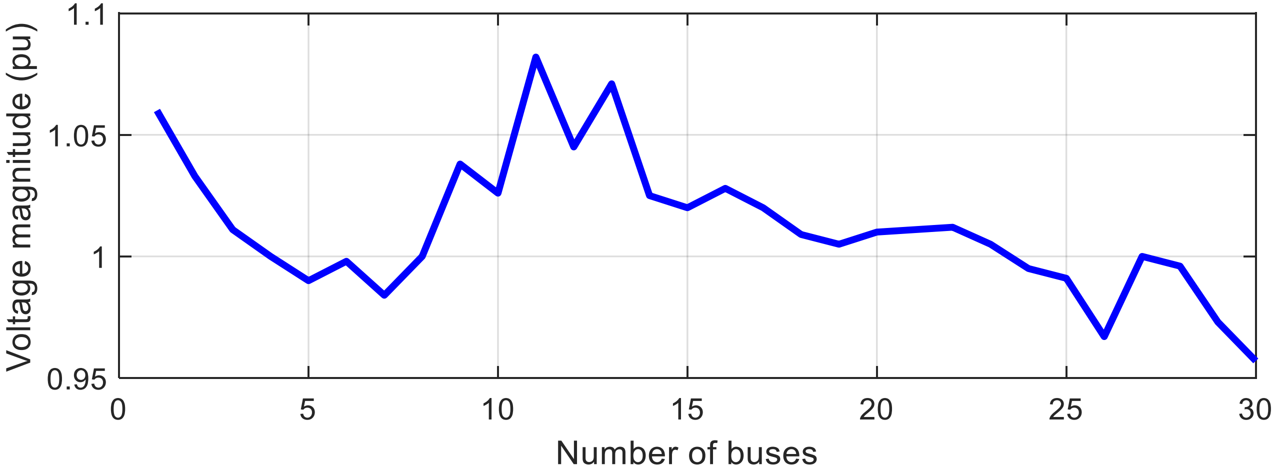
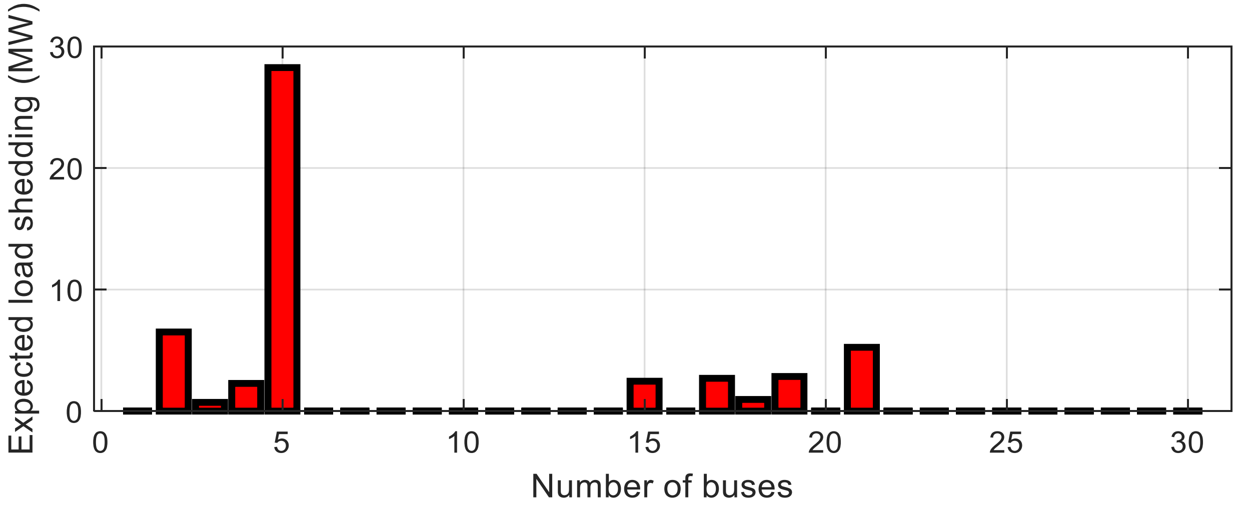

Iteration
i=i+1
Final
Iteration
Bus LS
$\begin{bmatrix} P_{(1,1)} & \cdots & P_{(1,s)} \\ \vdots & & \vdots \\ P_{(h,1)} & & P_{(h,s)} \end{bmatrix}$
Position and
velocity update of
each particle
Time montoring
Initial position x
and moving with
random initial
velocity v
Global best for this
iteration
Optimal Solution
(Optimal load
shedding)
Global Best
$G_{ibest}^{i+1} = \begin{bmatrix} P^{GB}{}_{(1,1)} & \cdots & P^{GB}{}_{(1,s)} \\ \vdots & \ddots & \vdots \\ P^{GB}{}_{(h,1)} & \cdots & P^{GB}{}_{(h,s)} \end{bmatrix}$
Particles Personal
Best

Results (IEEE 30-Bus)

Top rank	Bus number	Bus voltage (pu)	Total power losses	
			MW	MVAR
1	30	0.894	***Base case***	
2	26	0.906	17.60	22.24
3	29	0.913	***Loaded case***	
4	25	0.935	47.02	142.42



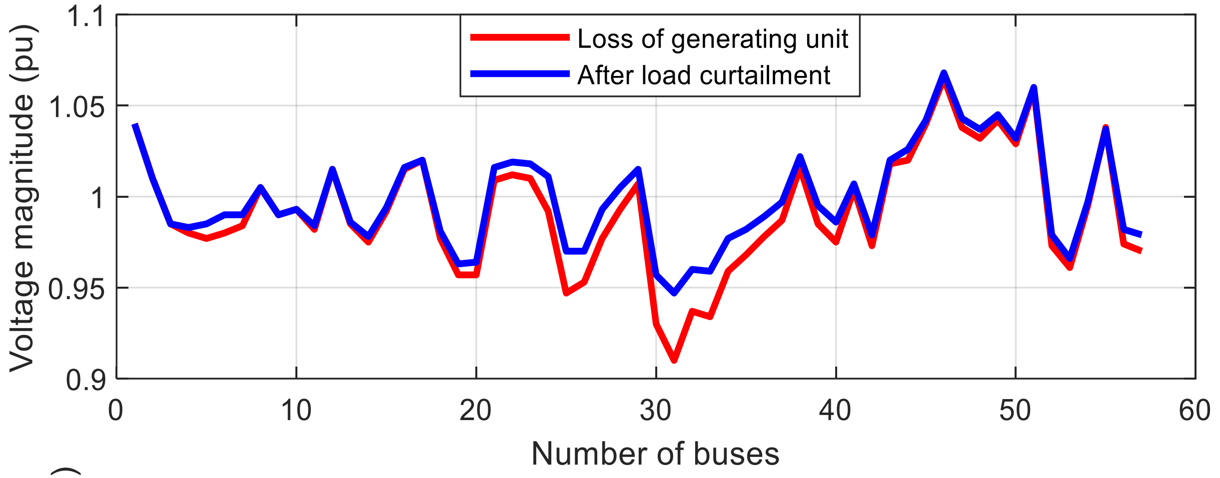
The assigned load for shedding to each bus is considered based on the voltage level and power system losses. Weak bus ranking is critical to avoid improper load reduction. The total power system loss is considered another index to ensure the ranked buses are optimal for load shedding.

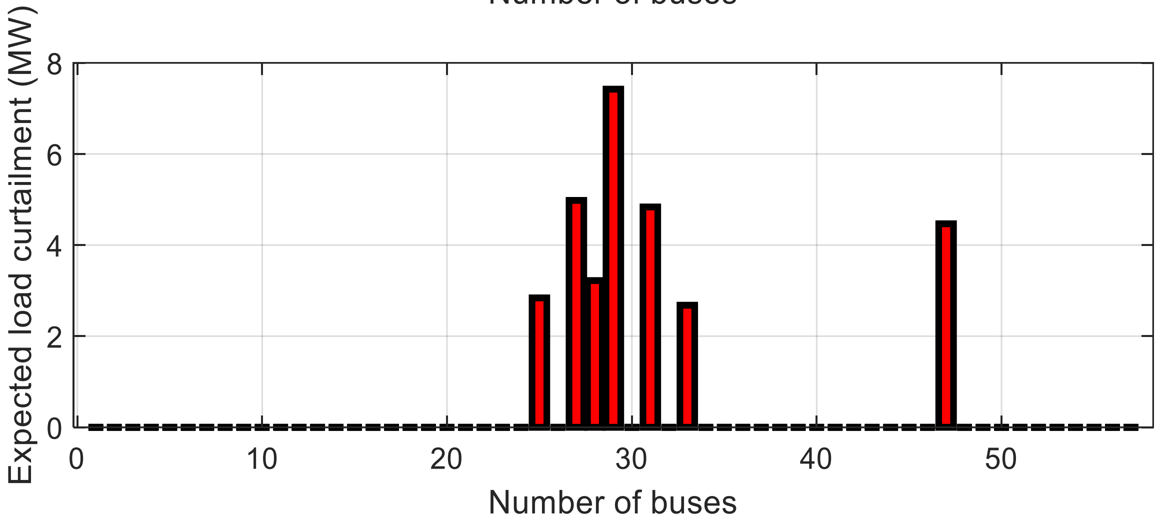


Results (IEEE 57-Bus)

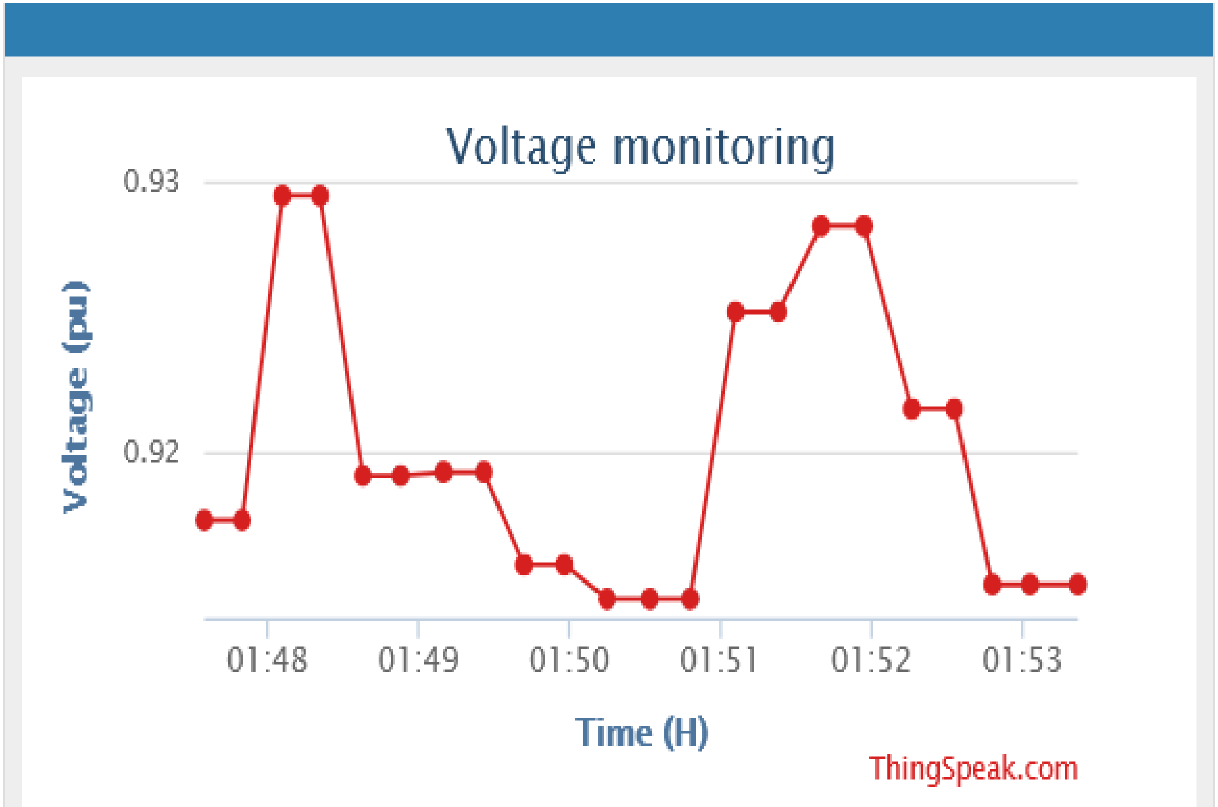
Total supplied power (MW)	Nominal demand (MW)	Total load shed (MW)	Total system losses (%)
1222.835	1195.800	0	2.211
1226.023	1195.800	Gen-outage (40MW)	2.465
1191.619	1165.239	30.451	2.214

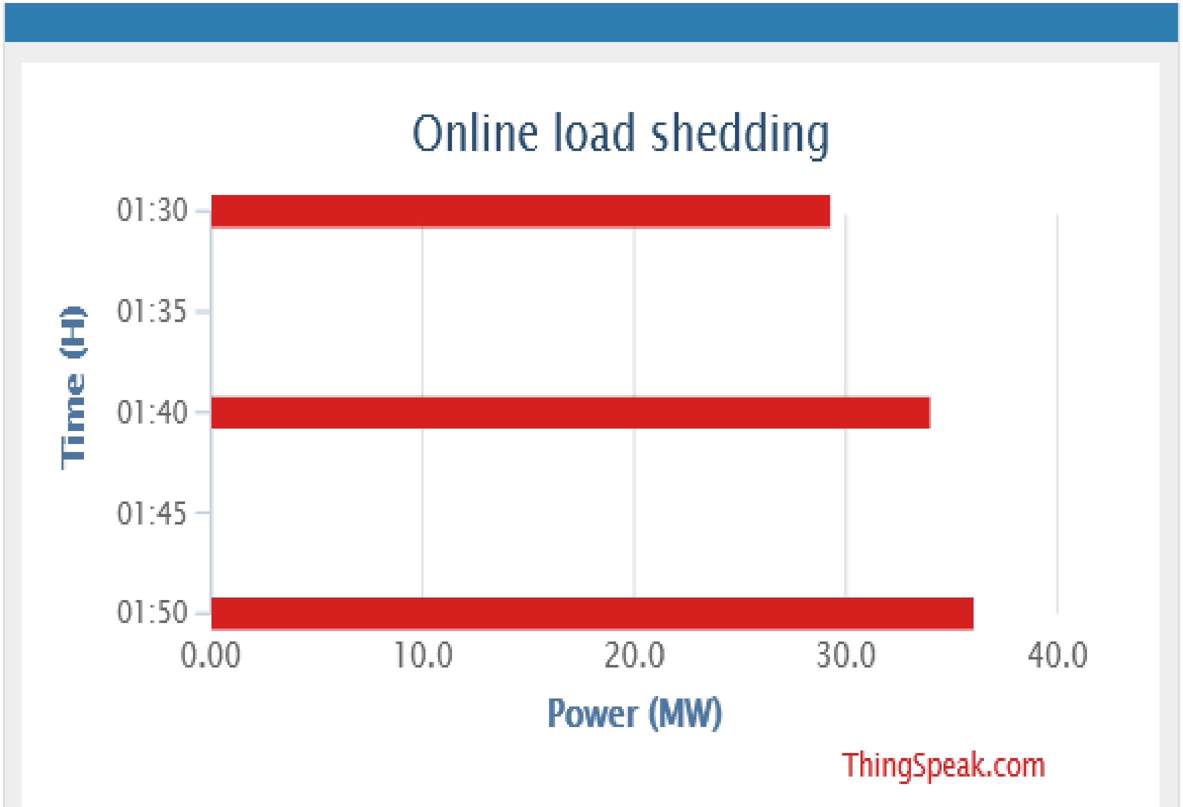
The deficit in the power supplied due to the loss of generation contingency is considered to measure the effect of the proposed optimized load shedding approach. It is observed from the Table and Figure that the system's stability can be maintained with less load shedding.





System Monitoring





The system has been monitored during the optimization process to enable online security assessment in a cloud computing environment.

Conclusion

The main paper's contribution is an optimized load shedding approach to mitigate cascading failure. This method employs the **PSO-based Newton-Raphson power flow method** with **cloud monitoring environments** to transfer data operating through the Internet of Things.

Thank You!