Discovery of false data injection attacks on power grid frequency controllers with reinforcement learning

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Introduction: Cyber security in power grid

Present Grid
- Conventional generation
- Synchronous generator

Future Grid
- More renewable energy
- Inverter based resources

- ✚ Hundreds of generators
- ✚ High Mechanical Inertia
- ▬ Linear control law
- ▬ Inflexible control

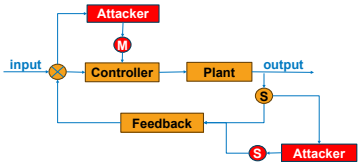
- ▬ Millions of inverters
- ▬ Low Inertia
- ✚ Flexible control
- ✚ Arbitrary control law

Long term advantage
Cleaner energy

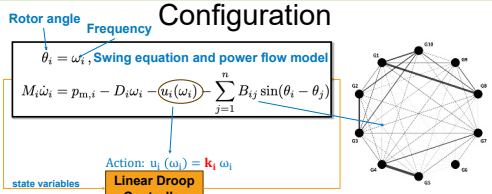
Long term security concern
Need more communication channels

Introduction: False data injection attack

- **Feedback loop assumption**
  - **Sensor value observed is unbiased**
- **False data injection attack**
  - **State estimation is modified**
  - **Modified control logic**



Configuration



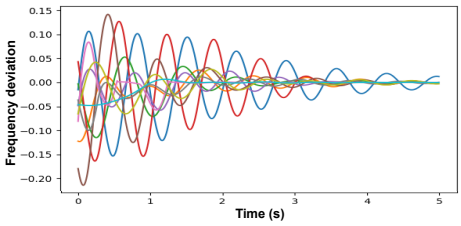
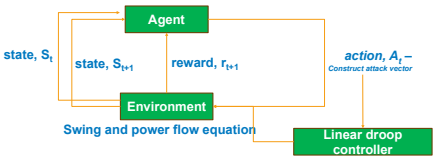


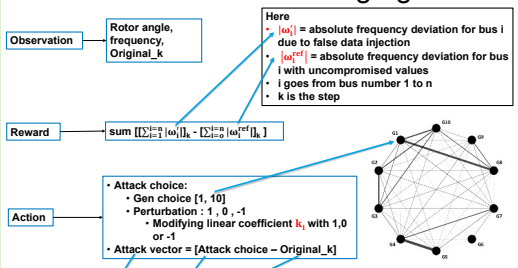
Fig 1: Linear droop controller for frequency deviation of reduced 10 bus system

Methodology



Assumption:
- Agent has access to the frequency, rotor angle and original linear droop coefficient value (Original_k)
- The agent chooses one generator to perturb with one attack choice at one time step
- Episode terminates at 5s i.e., 500 timesteps

Reinforcement learning agent



Manual false data injection attack

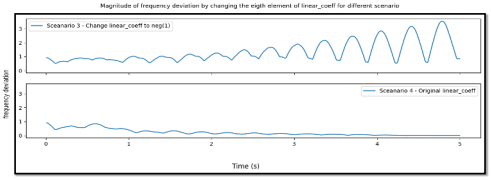


Fig 2: Manual FDI on generator 8 with perturbation of -1

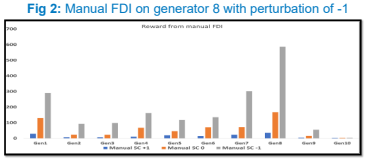


Fig 3: Reward earned by manual perturbation of each generator for different scenario

Results

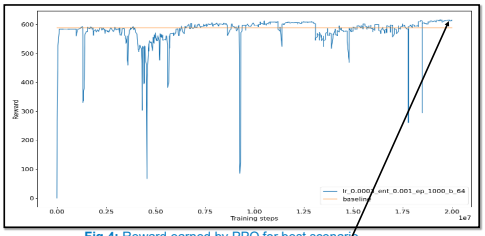


Fig 4: Reward earned by PPO for best scenario

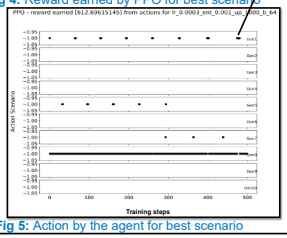


Fig 5: Action by the agent for best scenario

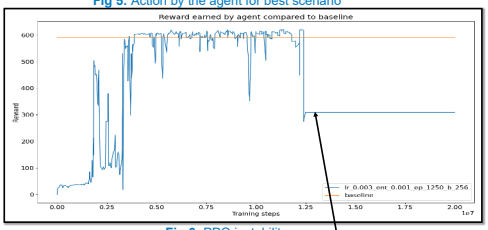


Fig 6: PPO instability

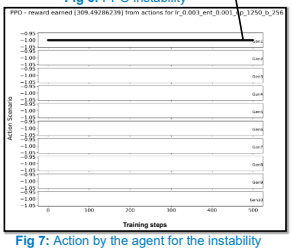


Fig 7: Action by the agent for the instability

Conclusion

- **Agent discovered that how to perturb a combination of generators**
- **Agent discovered perturbing generator 10 and 9 has no impact**
- **In some cases, agents demonstrated sign of "catastrophic forgetting"**
- **In future, we would like to add more complexity to the environment**
  - **Agent should avoid detection**
  - **Partially observable states**

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