"Cascading outage analysis tool"

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Summary

We report several advances in our cascading outage analysis tool. The advances include the improvements in the cascading outage analysis algorithm and the software design revision. Three additional features have been implemented for the cascading outage analysis algorithm: multiple initial disturbances; a substation identification algorithm; and additional initial disturbance types. More flexibility and expandability was achieved by revising the software design using design patterns. Additional outage checker considering system under-frequency events is being implemented currently.

A cascading outage analysis tool is under development at The University of Texas at Austin. Here, we report several advances in the cascading outage analysis algorithm and in the software design as well as an on-going effort involving system under-frequency checker algorithm development.

The previous, initial, implementation of the cascading outage analysis algorithm was as follows. Following the initial disturbance, the "outage checkers" determine if and when the resulting operating state, or "equilibrium" would result in protection equipment removing more elements from the system and therefore potentially precipitating further outages. If there are several protection actions identified by the outage checkers, then timing information from the outage checkers will determine which element would be, in fact, first disconnected. This element is removed from the power flow model. The process then repeats until either a complete system blackout occurs or no more protection actions are predicted to occur.

The following additional features have been implemented more recently:

- Multiple initial disturbances can be considered.
- A substation identification algorithm was implemented.
- Additional initial disturbance types can be considered.
    - Generator outage
    - Substation outage
    - Load bus trip

In the previous implementation, the cascading outage analysis tool could consider only single initial disturbance. Moreover, the type of initial disturbance was limited to be only a line outage. These limitations have been resolved in the current

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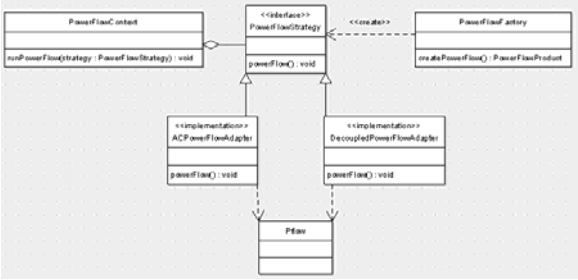
implementation. Furthermore, a substation identification algorithm was implemented and substation outages can be considered as initial disturbances.

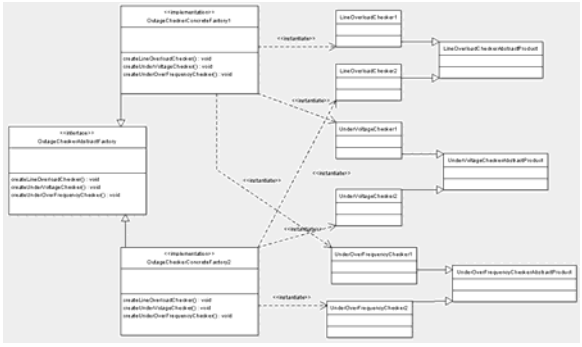
Another major accomplishment is revising the software design in order for more flexibility and expandability. We have adopted several so-called "design patterns" including the Adapter, Strategy, Factory Method, and Abstract Factory design patterns. The affected components from this design revision are the power flow module and the outage checker module.

The power flow module determines sequential equilibrium states for checking further outages. The cascading outage analysis tool utilizes an independent AC power flow module, PFlow, which has been developed by Commonwealth Associates Inc. and licensed to The University of Texas. In order to re-use this previously implemented module and provide flexibility to switch to or add different power flow modules and determine a specific module to run at run-time, three design patterns, the Adapter, Strategy, and Factory Method design patterns, have been adopted. The class diagram of the design is shown in the following figure.



Class diagram of the power flow module.

Our cascading outage analysis software is designed to have multiple outage checkers, with the capability for further different types of checkers to be added in future development. In the current implementation, there are two outage checkers for line overload and bus under-voltage protection. Both of the outage checkers are using the power flow algorithms. In order to choose the specific power flow module from multiple power flow modules dynamically in a consistent manner and to flexibly expand the outage checkers, the Abstract Factory design pattern was utilized as shown in the following class diagram.



Class diagram of the outage checker module.

In addition to the steady-state analysis based approach, we plan to add another outage checker for the protection from system under-frequency events. We have surveyed various models to assessing system under-frequency and are developing an algorithm.

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