Attributes Of
On-line Cascading Event Tracking and Avoidance Decision Support Tool

A Report Developed for PSerc Project S26: Risk of Cascading Outages

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May 30, 2006

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1. Introduction

At the grid level the grid operators are not sufficiently aware of the wide spreading cascading failures with respect to supranational interferences because of the limited monitoring and data exchange capabilities beyond the control areas [1]. Yet it is a fact that the modern power system operators are supervising one of the most complex systems of the society and are expected to take apt, correct and alert actions to ensure operational reliability and security of the power system. Under normal conditions they are able to sufficiently control the power system with sufficient automatic control support. Severe disturbances and complex unfolding of the post disturbance phenomena and interdependent events demand critical actions to be taken on the part of the operators which make them even more dependent on decision support and automatic controls at different levels which often results in worse power system conditions [2][3].

The market liberalization and push to operate the power system close to operational limits with less redundancy due to constraints placed by economical and environmental factors have made the operation more complex and exposed the power system to greater vulnerability to a disturbance, especially severe disturbances. There is indication in other industries (e.g., airline, nuclear, process control) that they employ a computational capability which provides operators with ways to predict system response and identify corrective actions. We think that power system operators should have a similar capability. The evolving power system demands ongoing and online operator training and capability enhancement to deal with any unforeseen initiating event/severe disturbance and unpredictable unfolding sequence of events.

To meet this challenging task of proper operator response and training, the attributes of the mid-term simulator are proposed. This simulator will be used on-line to prepare the operators against extreme contingencies. It is expected to be a generalized event based corrective control/decision support for the operators. Section 2 briefly describes the attributes of the blackouts. In Section 3 the attributes the proposed mid term simulator is presented. Section 4 concludes.

2. Blackout Attributes

Analysis of the blackouts summary slides that we have prepared indicates that the nature of the blackouts with respect to time may be roughly classified as either fast (less than 3 minutes) or slow. And when they are slow, they always involve a cascading sequence. It is for the slow types that we attempt to propose a simulator as a decision support tool for the operators. There are four typical stages of such cascading sequences [4].

1. Initiating contingency.
2. Steady-state progression (slow succession);
    - System becomes stressed with heavy loading on lines, transformers, and generator;
    - Successive events occur, typically the trip of other components with fairly large inter-event time intervals.
3. Transient progression (fast succession);
    - System goes under-frequency and/or under-voltage;
    - Large number of components begins tripping quickly.
4. Uncontrolled islanding and blackout.

An important attribute of the events in stage 2 is that they are almost always dependent events in that their occurrence depends on the occurrence of one or more earlier events. It is recognized that the probability of occurrence of successive events increases dramatically following the occurrence of a contingency. The time interval between an initiating event and successive events varies greatly. For example, the time between a fault and an inadvertent relay trip can be less than a second. However, if a fault followed by line clearing causes line overload and/or generator over-excitation, subsequent tripping may follow minutes or even hours later. The time interval may be long enough for an operator to initiate actions to mitigate the undesirable trend. From the slides we can see that almost 50% of the blackouts in the last 40 years were slow and 60% of them involved many cascading or dependent events.

3. Simulator Attributes

The methodology discussed in report 1 [5] forms the foundation for continuous tracking of the system topology to generate high risk extended contingencies list for online security assessment. The proposed simulator should have the following features [6]:

- Provide decision support in the face of unfolding events
- Provide "blackout avoidance" training tool for operators
- Continuously identify catastrophic event sequences together with actions operators can take to mitigate them
- Intelligently select triggering events based on substation topology using switch-breaker data already existing in topology processor
- Use current or forecasted conditions
- Based on mid-term (hours) simulation tool
- Have detailed protective relaying, generator etc modeling
- Store results for fast retrieval should an event occur

In keeping with the above a time domain simulator is the preferred analysis tool. However, it must be specialized to perform extended-term (several hours) of simulation quickly. This means it must model both fast and slow dynamics and be capable of lengthening time steps when fast dynamics are inactive. In addition, it must have the necessary intelligence to recognize when failure conditions are encountered, retrieve earlier conditions, and determine appropriate actions; it must also have modeling capability for a wide range of protection devices. Fig. 1 shows the proposed time domain simulator with desired capabilities of fast, long term, adaptive time step dynamic simulation of slow and fast dynamics and appropriate control action determination to arrest unfolding cascading event. The philosophy is to prepare and revise, track and defend.

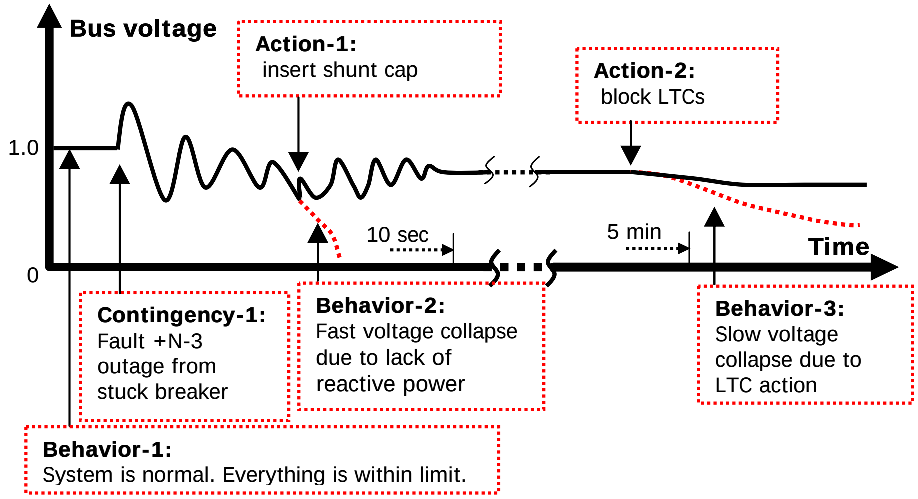

Fig. 1: Time domain simulator

Finally, in order to combine it with contingency identification and apply it online, it should be able to integrate with system real time information seamlessly, including switch-breaker data for automatic initiating event identification. In summary it should

- Model full range of dynamics:
  - Fast dynamics, including generator, excitation, governor
  - Slow dynamics, including AGC, boiler, thermal loads
- Model condition-actuated protection action that trips element
  - Generator protection: field winding overexcitation, loss of field, loss of synchronism, overflux, overvoltage, underfrequency, and undervoltage
  - Transmission protection: impedance, overcurrent backup, out-of-step
- Capability of saving & restarting from conditions at any time
- Fast, long-term simulation capability:
  - Simulate both fast and slow dynamics with adaptive time step using implicit integration method
  - Utilize sparsity-based coding
  - Deployable to multiple CPUs
- Intelligence to detect and prevent failures

Fig. 2 captures the proposed simulator's desired attributes in three dimensions of versatility namely

- Simulation model complexity
- Computational characteristics
- Decision Set Priority

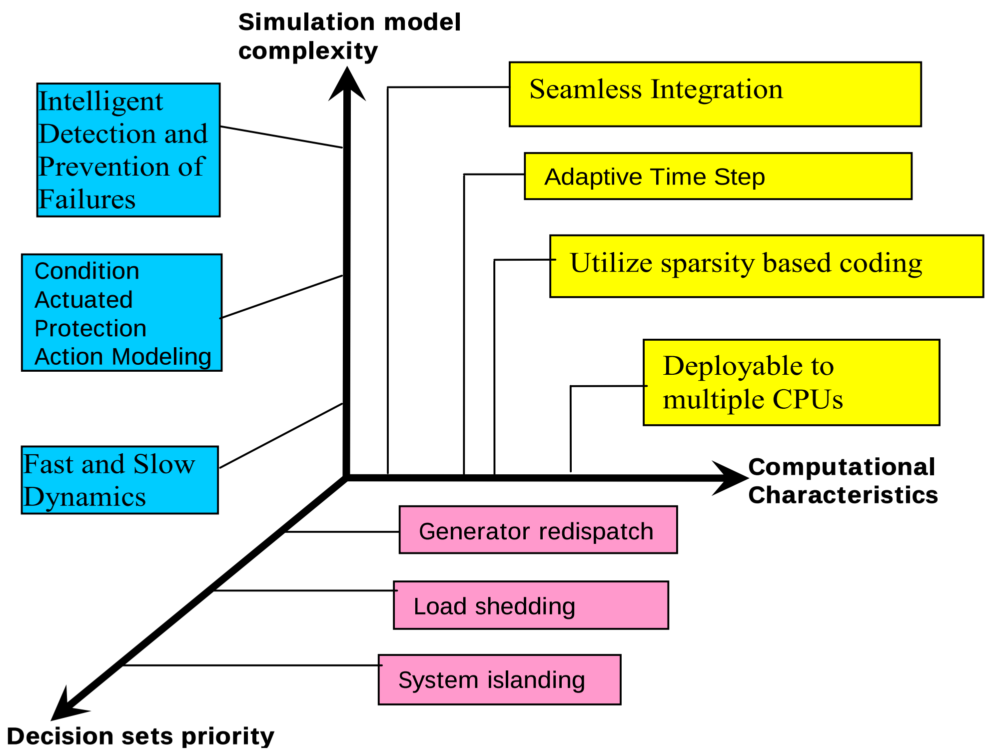

Fig. 2: Simulator Attributes (in terms of Decision set priority, Computational characteristics, and simulation model complexity)

4. Summary

- Preparing operators for rare events is fundamental to operating engineering systems having catastrophic potential and it has a precedent in air traffic control, nuclear, & process control.
- The goal is to generalize already-existing event-based special protection systems, so that response can be developed continuously on-line and can be actuated through a human operator.

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