Introduction to Smart Grids*

*SMART GRID
Fundamentals of Design and Analysis
by James Momoh, 2012

CHAPTER 3:

PERFORMANCE ANALYSIS TOOLS FOR SMART GRID DESIGN

LOAD FLOW STUDIES

Load flow studies are critical to system planning and system operation.

For example, data on peak load conditions assists planners in determining the **size of components** (conductors, transformers, reactors, and shunt capacitors), **siting new generation and transmission**, and **planning interties** with neighboring systems to meet predicted demand consistent with the Electric Reliability Corporation's (in charge) reliability requirements.

LOAD FLOW STUDIES

Load flow studies identify:

- line loads and bus voltages out of range,
- inappropriately large bus phase angles (and the potential for stability problems), component loads (principally transformers),
- proximity to Q-limits at generation buses,
- other parameters having the potential to create operating difficulties.

Intermediate load and off-peak (minimum) load studies are also useful, since off-peak loads can result in high voltage conditions that are not identified during peak loads.

LOAD FLOW STUDIES

Load flow studies **assist** system operators in:

- calculating power levels at each generating unit for economic dispatch
- analyzing outages and other forced operating conditions (contingency analysis),
- coordinating power pools.

In most instances, load flow studies are used **to assess system performance and operations under a given condition**.

CHALLENGES TO LOAD FLOW IN SMART GRID

Current legacy methods have weaknesses that need to be addressed prior to their use in analyzing smart grid performance and operations.

Four fundamental questions should be answered:

- What are the special features of the smart grid compared to the legacy system?
- What computations are needed in the case of smart grid?
- What specific directions are needed for developing a new power flow?
- What new features of the load flow make it suitable for smart grid performance and evaluation?

CHALLENGES TO LOAD FLOW IN SMART GRID

Other features to be considered in the development of the new load flow include:

- Condition adaptiveness of transmission and distribution to accommodate load flows comprising renewable generation
- Self-adaptiveness to ensure proper coordination
- High impedance topology matching for distribution network with randomness and uncertainty requiring intelligence analytical tools
- Since reverse power flow technique is possible, the use of FACTs devices to power electronics building blocks is essential.

CHALLENGES TO LOAD FLOW IN SMART GRID

Existing load flow performance tools capable of determining voltage, angle, flows, MW/MVAr, and scheduling dispatch are mostly offline although a few can give real- time results. To enhance load flow capabilities, the smart grid load flow process consists of the following steps:

1. Data acquisition for radial or mesh network
2. Existence of connection of data to assure network feasibility
3. Formulation of Y-bus for representing the interconnection of the system under study and determination of initial conditions
4. Solution of mismatch real and reactive powers and checking of mismatch by adjusting the initial conditions typically called the hot state
5. With the snapshot power demand (real power and reactive power demand), determining a feasible static voltage and angle to minimize mismatch

LOAD FLOW STATE OF THE ART: CLASSICAL, EXTENDED FORMULATIONS, AND ALGORITHMS

- The traditional load flow techniques used for distribution load flow are characterized by:
- Distribution systems are radial or weakly meshed network structures
- High X/R ratios in the line impedances
- Single phase loads handled by the distribution load flow program
- Distributed Generation (DG), other renewable generation, and/or cogeneration
- power supplies installed in relative proximity to some load centers
- Distribution systems with many short line segments, most of which have low impedance values

LOAD FLOW STATE OF THE ART: CLASSICAL, EXTENDED FORMULATIONS, AND ALGORITHMS

For the purpose of load flow study we model the network of buses connected by lines or switches connected to a voltage-specific source bus. Each bus may have a corresponding load composite form (consisting of inductor, shunt capacitor, or combination). The load and/or generator are connected to the buses.

The classical methods of studying load flow include:

1. Gauss–Seidal
2. Newton–Raphson
3. Fast Decouple

CONGESTION MANAGEMENT EFFECT

- Congestion is defined as a situation where load flows lead to a violation of operational limits, that is, maximal thermal loading, voltage stability, or the $n - 1$ security rule.
- Net Transmission Capacity (NTC) is the additional transaction potential between zones A and B given a base scenario of injections.
- In a meshed network, intrazonal injection variations will influence cross-border load flows and are an important factor in the determination of transmission capacities.

LOAD FLOW FOR SMART GRID DESIGN

Load flow tools that incorporate the stochastic and random study of the smart grid could be modeled with the following implementation algorithm.

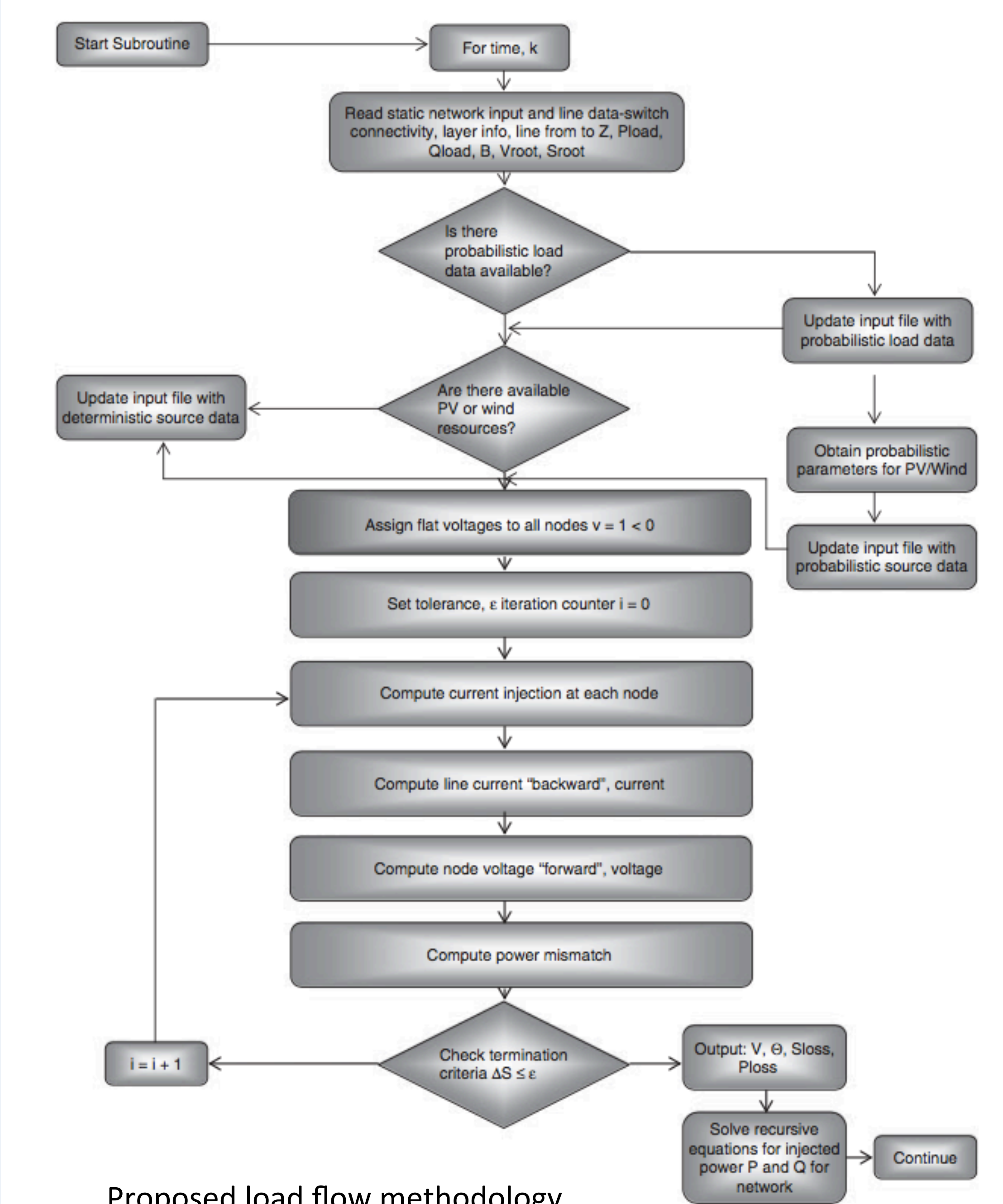
Conditioning the load flow topology will require a new methodology and algorithm that will include feeders and the evolution of a time-dependent load flow. This method has been proven in terms of characteristics and usage in power system planning and operation. Hence, the interoperability of RER with smart grid specifications could account for adequate use of current methodology to perform analysis in both usual and alert states.

LOAD FLOW FOR SMART GRID DESIGN

The implementation algorithm proposed will extend the following capability:

- Model input of RER and load will be changed to account for variability; the input will have to include some power distribution flow so as to advance the congested value of new estimate of *Pf*, *Qg*, and *Pd*, *Qd*. These attributes also have a unique load appropriate effectiveness in the performance study.
- Sparsity may be affected because the loads of RER may be widely distributed, that is, load and size of RER has to be considered.
- Computational challenges in new load flow with RER for smart grid that include the stochastic model may affect the independent computation.

LOAD FLOW FOR SMART GRID DESIGN

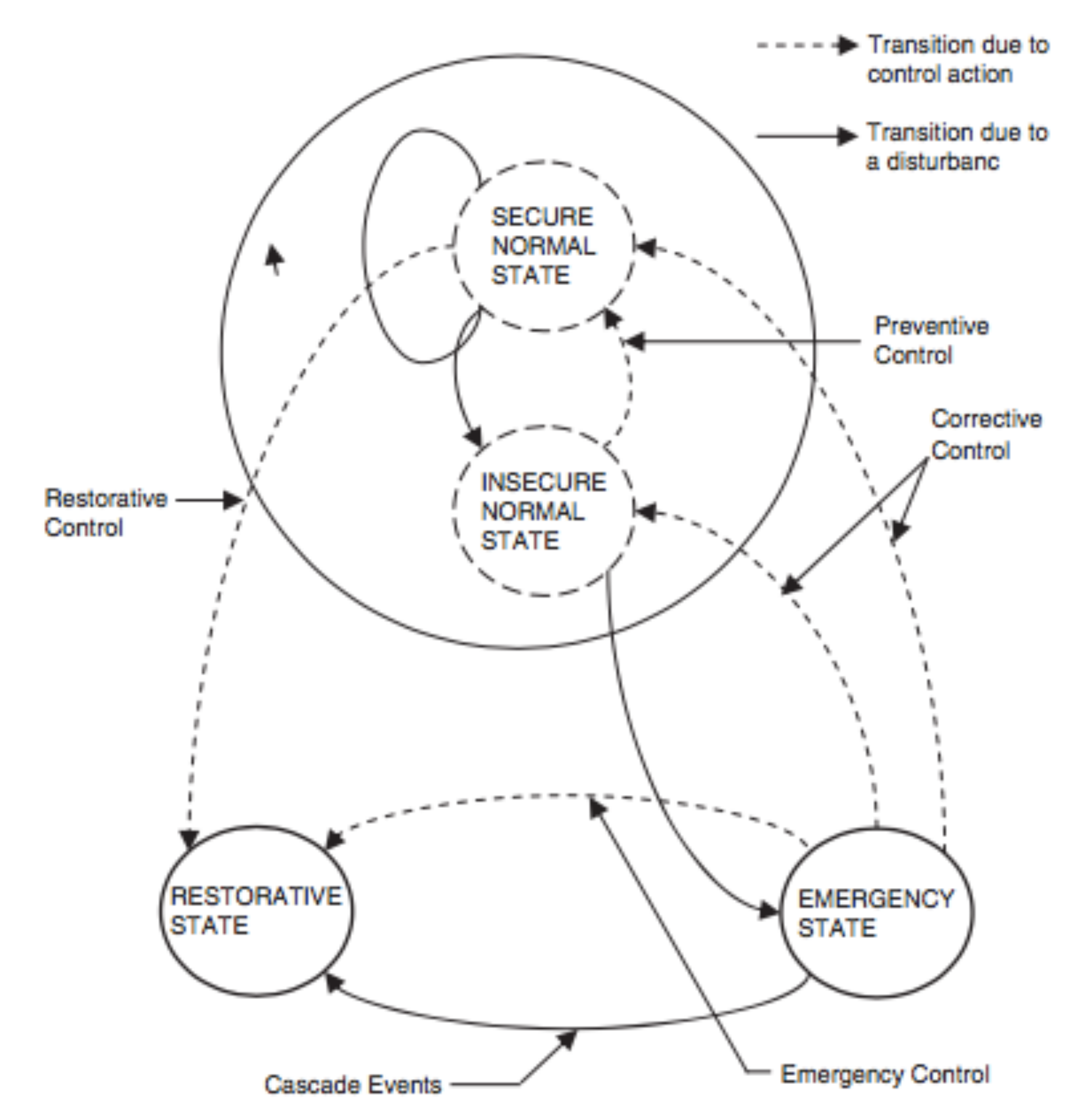


Proposed load flow methodology

STATIC SECURITY ASSESSMENT (SSA) AND CONTINGENCIES

System security refers to the ability of the power system to withstand probable disturbance with minimal disruption of service. In an operational environment, security assessment involves predicting the vulnerability of the system to possible disruptive events in real time. Actual operating conditions change constantly because of maintenance requirements, forced outages, and load patterns. The important options available to improve upon an insecure condition include starting an available unit, rescheduling generation, or asking for assistance from a neighboring system.

STATIC SECURITY ASSESSMENT (SSA) AND CONTINGENCIES



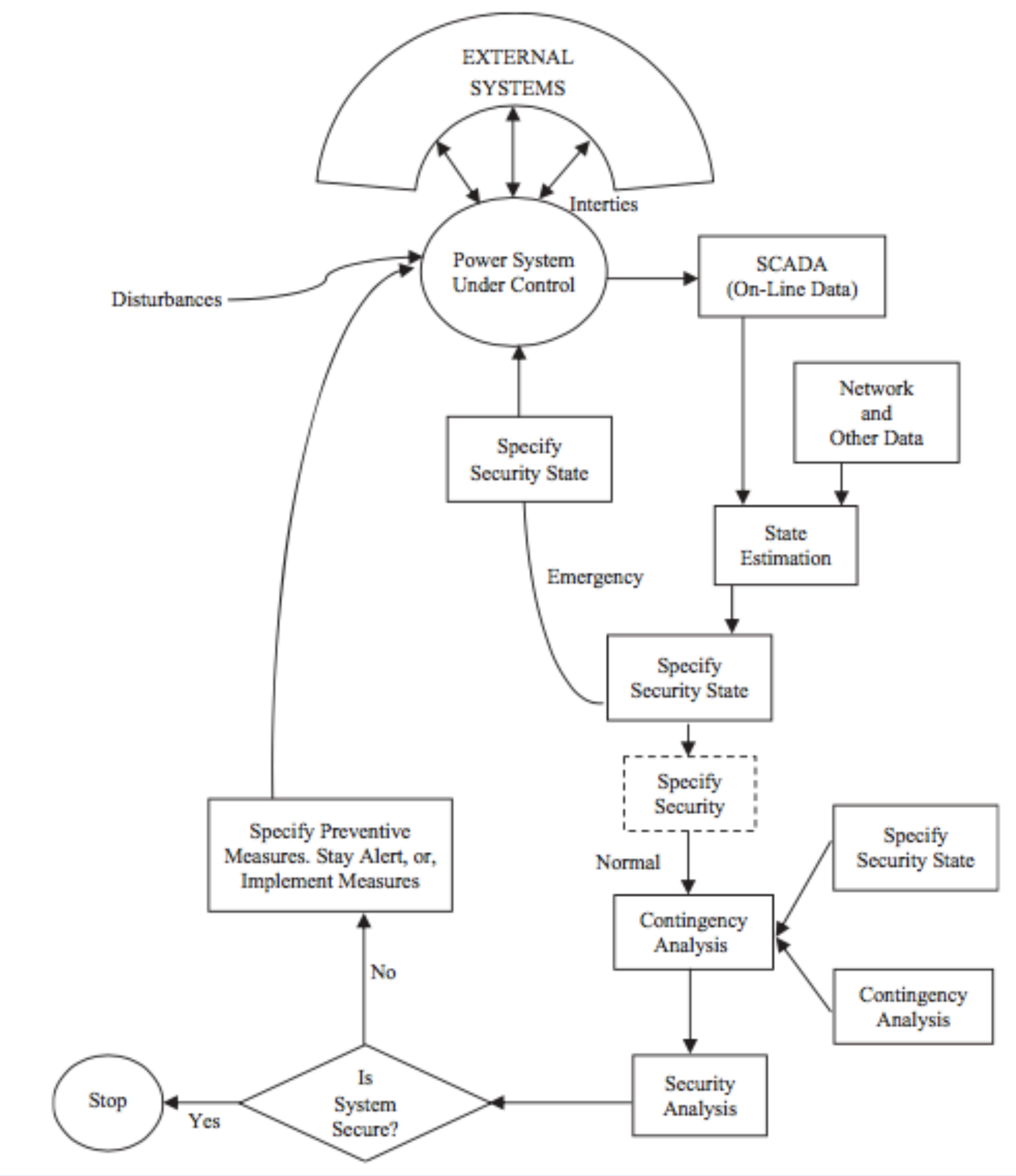
DyLiacco's security-state diagram

STATIC SECURITY ASSESSMENT (SSA) AND CONTINGENCIES

The concept of DyLiacco’s security- state diagram shows the principal operating states:

1. Secure or normal state: all system loads are satisfied at the specified voltage levels
2. Emergency state: some operating limits are violated, for example, overloaded lines
3. Restorative state: some loads are not met, that is, partial or total blackout, but the operating portion of the system is in a normal state.

STATIC SECURITY ASSESSMENT (SSA) AND CONTINGENCIES



CONTINGENCY STUDIES FOR THE SMART GRID

Contingency studies are proposed planning/operation tool for assessing the impact of unit or line outage in an integrated smart grid environment. This could be a single or multiple line outages called $N - 1$, $N - 2$, $N - 3$, . . . contingency. There are two types of contingency:

1. AC automatic contingency screening/filtering
2. AC automatic contingency control

CONTINGENCY STUDIES FOR THE SMART GRID

SSA is well known for classical power system.

The weak points are: includes

- Develop security measure to aid improvement in recommendation and display
- Selection of weighting measure
- Exponent factors
- The probability of selecting a contingency
- Lack of human intelligence and relative information on knowledge-base for decision-making by nonexperts. Work by the author has been planned using ES, ANN, and fuzzy sets. These schemes do not include time against sources, variability in selecting parameters for contingency studies.