Introduction to Smart Grids*

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

CHAPTER 5:

Computational Tools For Smart Grid Design

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- **Hybridizing the optimization techniques and application of Smart Grid**
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INTRODUCTION

Discussing the answers of following questions

- Are the tools sufficient for modeling and accounting for adequate models of the system as it incorporates variability and randomness of RER?

- Can the tools manage stochasticity and randomness in the system?

- Can the tools address predictivity and the anticipatory nature of the problems encountered?

INTRODUCTION

The classical optimization tools currently used cannot handle the adaptability and stochasticity of smart grid functions. Thus, the computational tools and techniques required are defined as a platform for assessment, coordination, control, operation, and planning of the smart grid under different uncertainties.

The competitive schemes will be defined, which are able to handle:

- Inadequate models of the real world.
- Complexity and large size of the problems which prohibit computation using computational intelligence.
- Solution method employed by the operator which is incapable of being expressed in an algorithm or mathematical form
- Decision-making by operator is based on fuzzy linguistics description.

DECISION SUPPORT TOOLS

- **Decision Support Tools combine:**
  - game theory
  - decision support systems
  - analytical hierarchical processes (AHP)
- These tools are used for:
  - computation of multiobjective
  - and risk assessment in smart grid planning and operations

DECISION ANALYSIS

- **Decision Analysis**
  - makes an uncertain problem perfectly rational decision that is based on numerical values for comparing and yielding fast results
  - relies on information about the alternatives.
  - This diversity in type and quality of information calls for methods and techniques that can assist in processing
  - includes many procedures, methods, and tools for identifying, clearly repre- senting, and formally assessing the important aspects of a decision situation.

DECISION ANALYSIS

- Multi-criteria decision analysis (**MCDA**) is a form of DA
  - supports decision-maker(s) when a problem involves numerous conflicting evaluations.

  MCDA highlights these conflicts and derives the path to a compromise in a transparent process.

- Analytical hierarchical processing (**AHP**) is another form of MCDA.

DECISION ANALYSIS

DA must be implemented with care.

If the available data are inadequate to support the analysis, it is difficult to evaluate the effectiveness, which will lead to oversimplification of the problem.

DA is particularly useful in;

- handling multiobjective functions,
- or attaining several goals of the smart grid where risk and possibility are included.

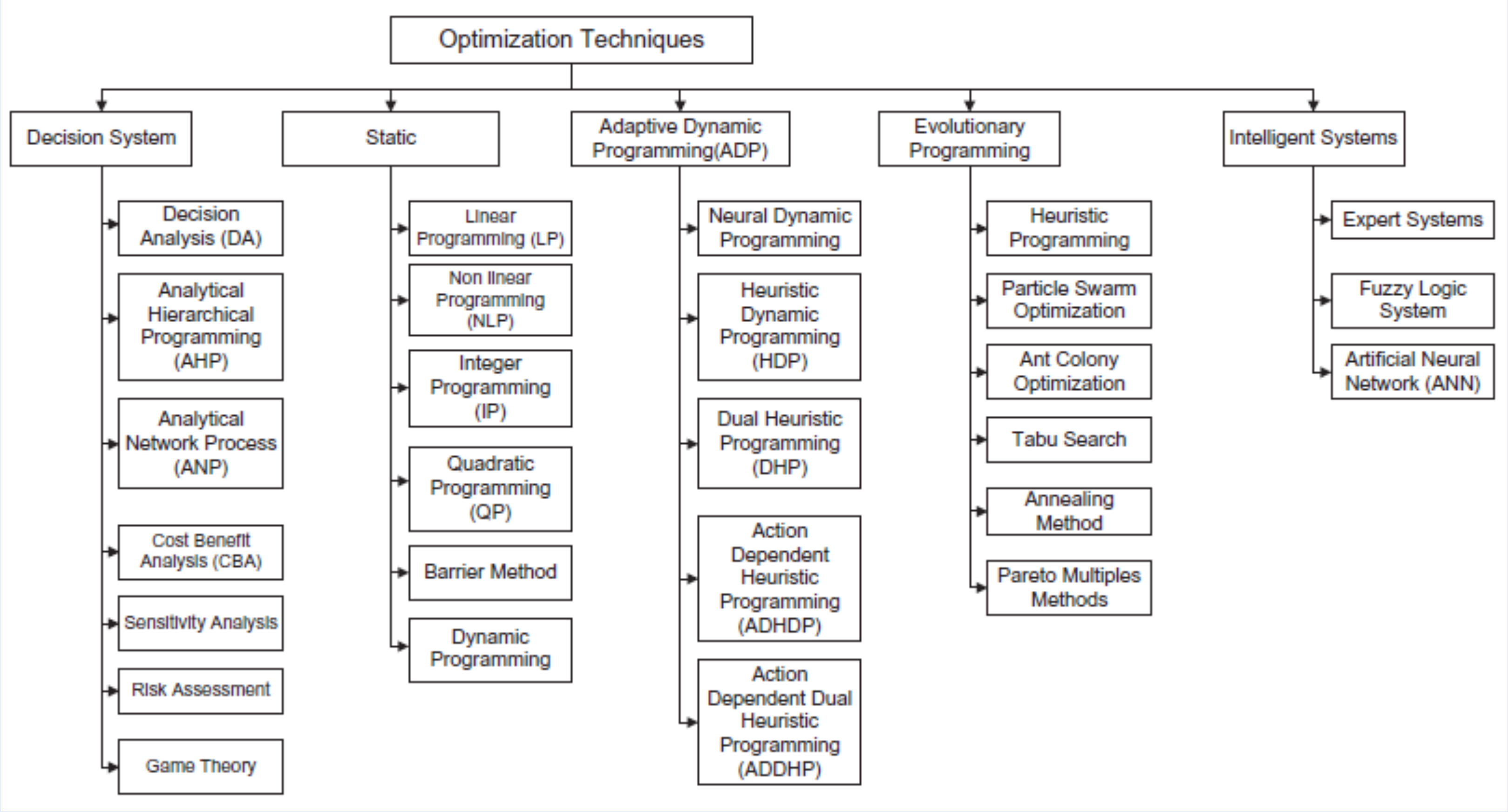
Analytical Hierarchical Programming (AHP)

- **AHP** is a **decision-making** approach;
  - presents the alternatives and criteria
  - evaluates the trade-offs
  - performs a synthesis to arrive at a final decision

- **AHP** is appropriate for cases involving both **qualitative and quantitative analyses;**
  - In multicriteria decision – making
  - In planning and resource allocation
  - In conflict resolution
- **AHP**, in its general form, is a **nonlinear framework** for carrying out both deductive and inductive thinking

OPTIMIZATION TECHNIQUES

- Consist of **static and dynamic techniques** for optimization:
  - linear programming
  - nonlinear mixed - integer programming (MIP)
  - dynamic programming (DP)
  - Lagrangian relaxation methods



Linear Programming

- Linear programming uses a mathematical model to describe the problem with **linear objectives and linear constraints**.

- Appling the linear programming method to the smart grid requires improving the it to accommodate the grid's stochasticity, predictivity, adaptivity, and randomness.
- The **traditional linear method** is confined to static problems and thus is **insufficient** for **smart grid implementation**.

Nonlinear Programming

- Nonlinear programming (NLP) typically employs Lagrangian or Newtonian techniques for constrained and unconstrained optimization problems.
- The approach assumes that all objective functions are modeled as smooth and continuous functions.
- Not suitable for Smart Grids, need to be developed to involve adaptive, predictive and stochastic algorithms.

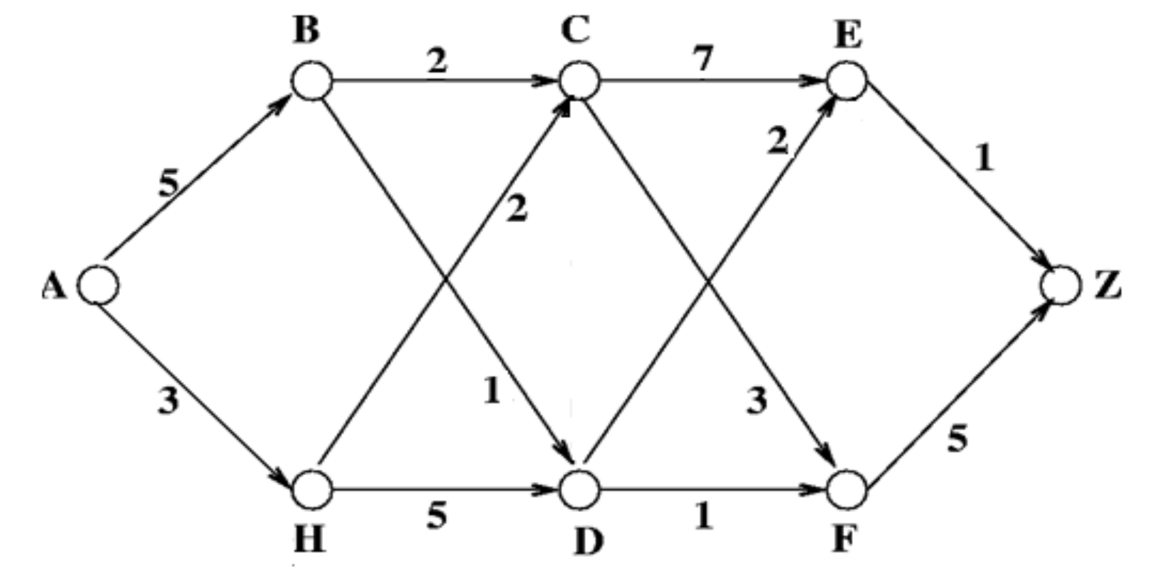
Integer Programming

- Special case of LP where all or some of the **decision variables** are restricted to **discrete integer values**

- Note that the direct use of **these techniques** for solving the smart grid optimization problem will be **limited**.
- Because they are generally **static** and are not designed for handling real-time and dynamic optimization problems.

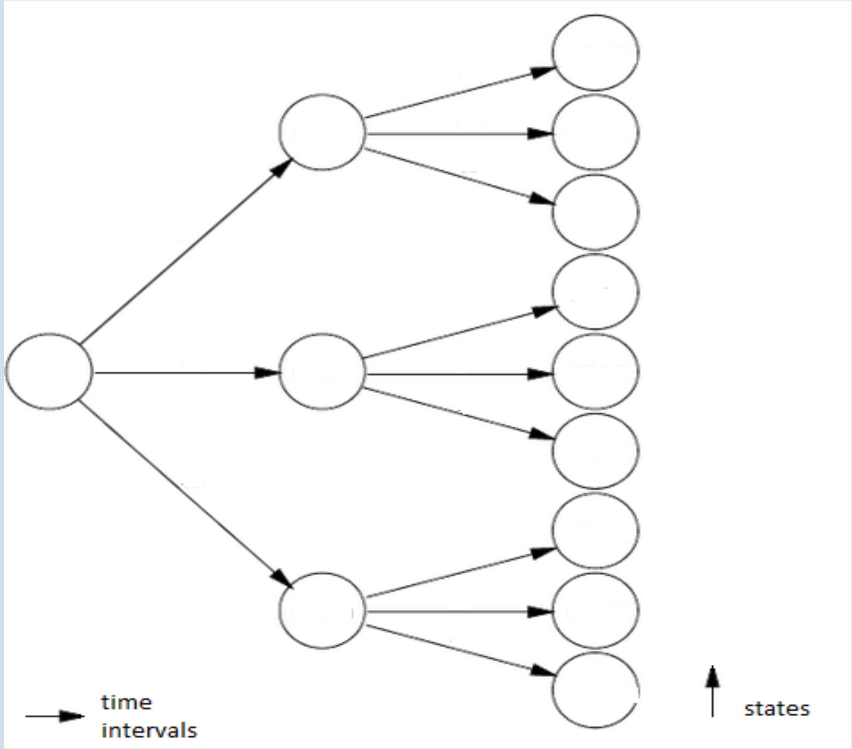
Dynamic Programming

- It is used for **multistage problems**.
- it **solves** a **multivariable problem** by solving a series of single variable problems.
- It is a **candidate optimization technique** for handling time variability and noise in the objective and constrained optimization problem.



Stochastic Programming-Chance Constrained Programming

- A framework for modelling the optimization problems which involve ambiguity and uncertainty
- A way to join these uncertainties to the cost minimizing unit commitment problem.
- Multi-stage operation representing the generating levels of generator is conducted during the time intervals to be planned



Heuristic Optimization

- Model a new objective function to account for customer and welfare power uncertainty
- Model RER to account for stochasticity and variability
- Update the model and simulate
- Define new system components' performance in time
- Solve the probabilistic load flow for base case studies and include new contingency set to define violations
- Select appropriate optimization technique which may include heuristic program technique and hybrid or ADP, methods that define the impact of predictivity and stochasticity as optimum.

Artificial Neural Networks (ANN)

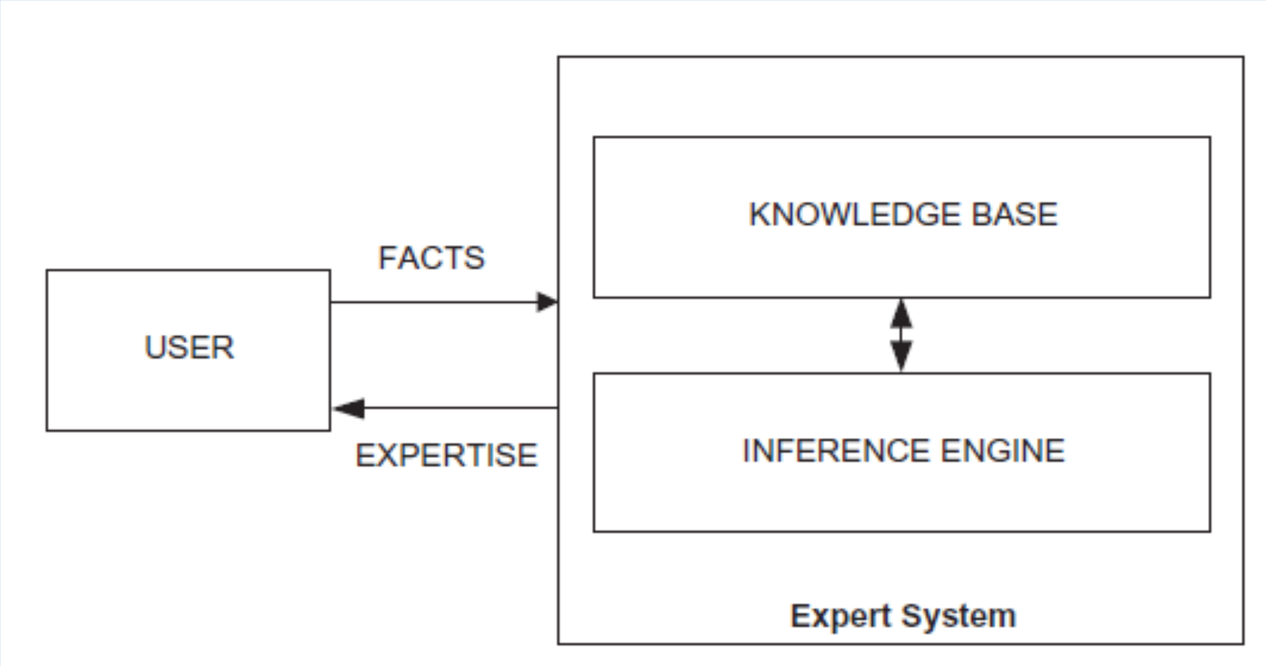
- ANN have the ability to classify and recognize patterns in a large quantity of data through training and tuning of the algorithm
- ANN learn by example
- Adaptive learning: Ability to learn how to do tasks based on the data given for training or initial experience.
- Self - organization: Creates its own organization or representation of the information received during learning period
- Fault Tolerance via Redundant Information Coding: Partial destruction of a network leads to the corresponding degradation of performance.

Heuristic Optimization-ANN

- For a unit commitment problem:
- Typical load demand curves and corresponding unit commitment schedules are stored in this database
- In order to obtain more optimal solutions, enlarged dimension of historical data should be employed.
- For high quality schedules, neural networks need to be well trained
- As much as possible case should take place to handle the different constraints.

Heuristic Optimization-Expert System

- Heuristic or rule - driven decision making



Fundamental components of an expert system

Heuristic Optimization-Expert Systems

- Optimal load shedding, resource allocation such as VAr, discrete control (series capacitors, ULTCs, and so on), and economic dispatch
- Fuzzy Logic :
- Handle the concept of partial truth, which are the truth values between " completely true " and " completely false. "
- Used to determine whether the process variables are within acceptable tolerances
- In smart grid design, many real-time decisions reuquire attribute of fuzziness.

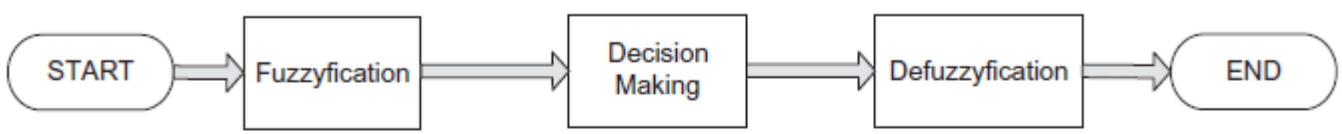
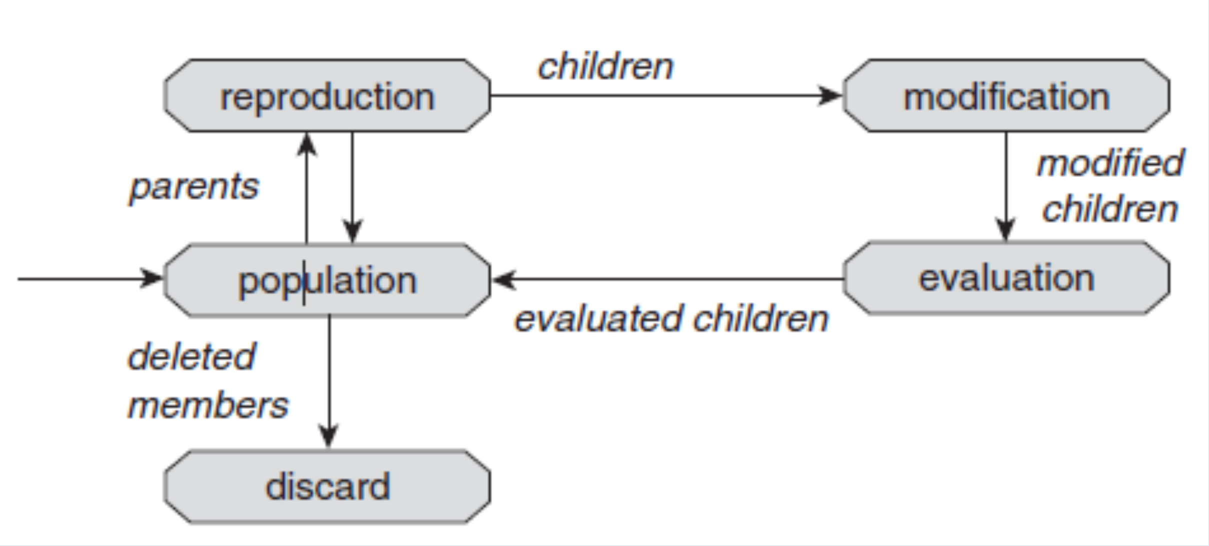


Figure 5.4. Simplified block diagram of fuzzy logic approach.

Evolutionary Computational Techniques

- Use population of individuals
- **Genetic Algorithm:**
- Power system expansion and structural planning
- Operation planning, and generation, transmission, and distribution operation
- Analysis for Var planning requiring real - time operation with uncertainty and randomness



Evolutionary Computational Techniques – Partical Swarm Optimization

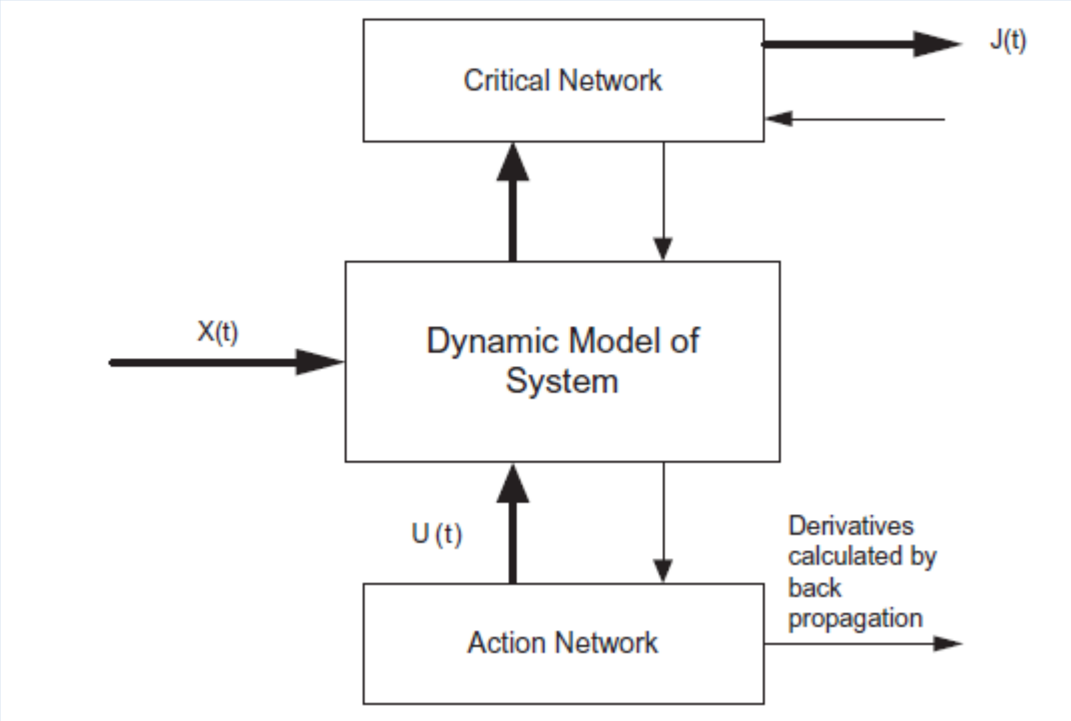
- Mimics the social behavior of bird flocking and fish schooling to guide the particles ’ search for globally optimal solutions
- To emulate the success of neighboring individuals and their own successes
- Discovering optimal regions of a high dimensional search space
- Lbest provides a local best, utilizing a ring network topology and a subset of the swarm as the neighborhood of the particle
- The gbest presents the global best where the neighborhood for the particle taken to be the swarm

Evolutionary Computational Techniques – Ant Colony

- Priori information about the structure of a promising solution
- Posteriori information about the structure of previously obtained good solutions
- Uses computational concurrent and asynchronous agents termed a colony of ants that move through states of the problem corresponding to the partial solutions.
- Trail evaporation action decreases all trail values over time
- Protective actions implement centralized actions which cannot be performed by single ants such as the starting of a local optimization procedure, or the update of global information used to decide whether to bias the search process from a nonlocal perspective

Adaptive Dynamic Programming Techniques

- Time dependency of the deterministic or stochastic data required for the future



Pareto Methods

- Min $F(x) = (f1, f2, \ldots, fm) T$
- $x \in N$
- s.t
- $g(x) = 0$
- $h(x) \leq 0$
- $a \leq x \leq b$
- One - at - a - time strategy: A multiobjective optimizer may be applied repeatedly with the goal each time of finding one single Pareto - optimal solution
- A feasible solution X^* is Pareto optimal if there is no other improved feasible point X such that $fk(X)\ fk(X^*)$ with strict inequality for at least one condition
- Simultaneous strategy: This approach utilizes EA due to the population or archive - based approach to facilitate a parallel search. The effi ciency of this method is greatly improved due to the reduced need for multiple applications of the optimization

Hybridizing the optimization techniques and application of Smart Grid

- Immunized - neuro systems, immunized - swarm systems, neuro - fuzzy systems, neuro - swarm systems, fuzzy - PSO systems, fuzzy - GA systems, and neuro – genetic systems. These hybrids (Table 5.1) are necessary to harness the advantages of the various paradigms of computational intelligence [7] for addressing the smart grid functions and capability to achieve self - learning capability

	Fuzzy	GA	AOC	ANN	EP	PSO	ADP
Fuzzy		X	X	X	X	X	X
Genetic Algorithm (GA)	X			X	X		X
Ant colony optimization (ACO)	X						X
Artificial Neural Networks (ANN)	X	X			X		X
Evolution programming (EP)	X	X		X			X
Particle Swamp Optimization (PSO)	X	X		X	X		
Adaptive Dynamic Programming (ADP)	X		X			X	

Computational Challenges

- Their optimal selection based upon the specific application and location
- Data availability is another challenge, enforcing the need to develop sensor and communication technology to facilitate the acquisition of real - time or just - in - time data
- **Software/hardware:** Is the tool to be developed software only or is some hardware required for integration and implementation?
- **Integration:** How will software/hardware be integrated into the system? Will it replace an existing tool or be integrated into an existing package/tool?
- **Location of installation** : Where will a tool be located and used; for example, LAN or WAN? Will it be necessary at all generating points or load points, at substation levels, or at the customer level?
- **Robustness:** How will the tool be implemented for ease of application and robustness?
- **Sensitivity:** What degree of sensitivity is required for satisfactory functioning?
- **Standards:** Have existing standards been identified or developed for utilization of the tool in similar environments?

End..

THANKS..

QUESTIONS?