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Assessment Of Online Voltage Security based on Voltage Stability Indices and FDT

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Abstract- Now a-day power networks all over the world need to transfer bulk amount of power. This has resulted in required vast interconnection of grids for assuring reliability, security, stability and economic operation. The challenges to ensure smooth system operation with stressed grid and averting system blackout provided the stimulus for research on voltage security. Voltage stability indices aid the security studies. Real-time voltage security assessment is based on synchronized pharos measurement obtained from phasor measurement units (PMUs). For fast accurate handling of data to synthesize information in order to estimate system security state decision tree (DT) approach of data mining is opted. Power system operating constraints are soft constraints, to implement the situation in real-time and improve decision making abilities at the overlapping and conflicting security boundaries present scheme adopts fuzzy decision tree (FDT).

The decision tree is trained offline considering past representative operating conditions, identify critical attributes as security predictors and periodically updated incorporating new operating conditions for robustness improvement. The status of critical attributes are obtained from PMUs and compared with thresholds priory defined by FDTs. The decision at the leaf nodes considers the whole path, i.e. from the root to the terminal node including membership function of security predictors. As classification and prediction by decision trees are fast, reliable, comprehensible the present scheme employs FDT and resolve conflict in decision making by prognosticating system security status with the aid of voltage stability indices (VSI) and thereby easing the operators' role and to some extent alleviating the risk of failure. The indices helps to identify security status from the solution of basic power flow equations, i.e. system real-time measurements such as voltage magnitude, phase angle, bus injected power, branch flows etc.

Key terms- Voltage security assessment, Pharos measurement unit, Decision tree, Fuzzy decision tree, Voltage stability indices

INTRODUCTION- Energy demand at the load centers around the globe has been increasing rapidly. This has pushed the operating point close to stability limits and thereby increased in voltage security issues and frequency of corresponding outages. In the present scenario grids operating with stressed operating point due to elevated load demand has resulted in noteworthy voltage limit deviations with respect to the imposed constraints due to which the issue of voltage collapse is looming prominently. The urgency for ensuring secure system operation has heightened the need for voltage security assessment. Due to emergence of fleet of sophisticated devices more and more data become available for the system study. Tactful utilization of data available for analysis and assessment of voltage security issues is fueled by machine learning, which has provided an evolutionary breakthrough in developing efficient and reliable tool for fast, accurate decision making under critical conditions with voltage stability indices acting as a vital tool in estimating system security status i.e. proximity to voltage collapse or signifying the stress of current operating point on power network.

This paper concerns with the research on synthesis of fuzzy rule- based DT approach of machine learning considering multi-class decision at terminal node to counter conflict in decision making at security boundaries and selection of parameters to take a time-stamp of power system operating conditions replicating different loading conditions.

MAJOR GRID BLACKOUTS

Grid blackout synonymously termed as voltage collapse. Voltage collapse majorly occurs due to sudden change in network topology, strikingly large unbalance between demand and generation. This can be explained in short as a phenomenon traced by wide spread decline in voltage profile usually initiated by lines, transformers, and generators tripping and disturbances in consumption patterns resulting in voltage drop due to scarcity of reactive power reserves in power system [Shahidehpour, 2014]. A list of major blackouts is presented in table 1.1.

Table 1.1 Major Grid Blackout in world

Source: [Shahidehpour, 2014]

Sl. No.	Date	Country
1	09/11/1965	10 states in northeast US
2	5/1977	Miami, US
3	7/1977	New York city, US
4	7/1999	New York city, US

Sl. No.	Date	Country
5	11/3/1999	Brazilian power system
6	2/01/2001	India
7	14/08/2003	Northeast of US and CANADA
8	28/08/2003	South London
9	7/11/2003	Most of Chile
10	25/5/2005	Moscow, Russia
11	4/11/2006	European Power System
12	30/7/2012-31/07/2012	India(Worlds' largest blackout recorded)

Mechanism of black out can be understood on a fly from the figure 1.1. Power system operating at normal operating conditions may subjected to the vagaries of system operations such as contingency conditions which may lead to instability events.

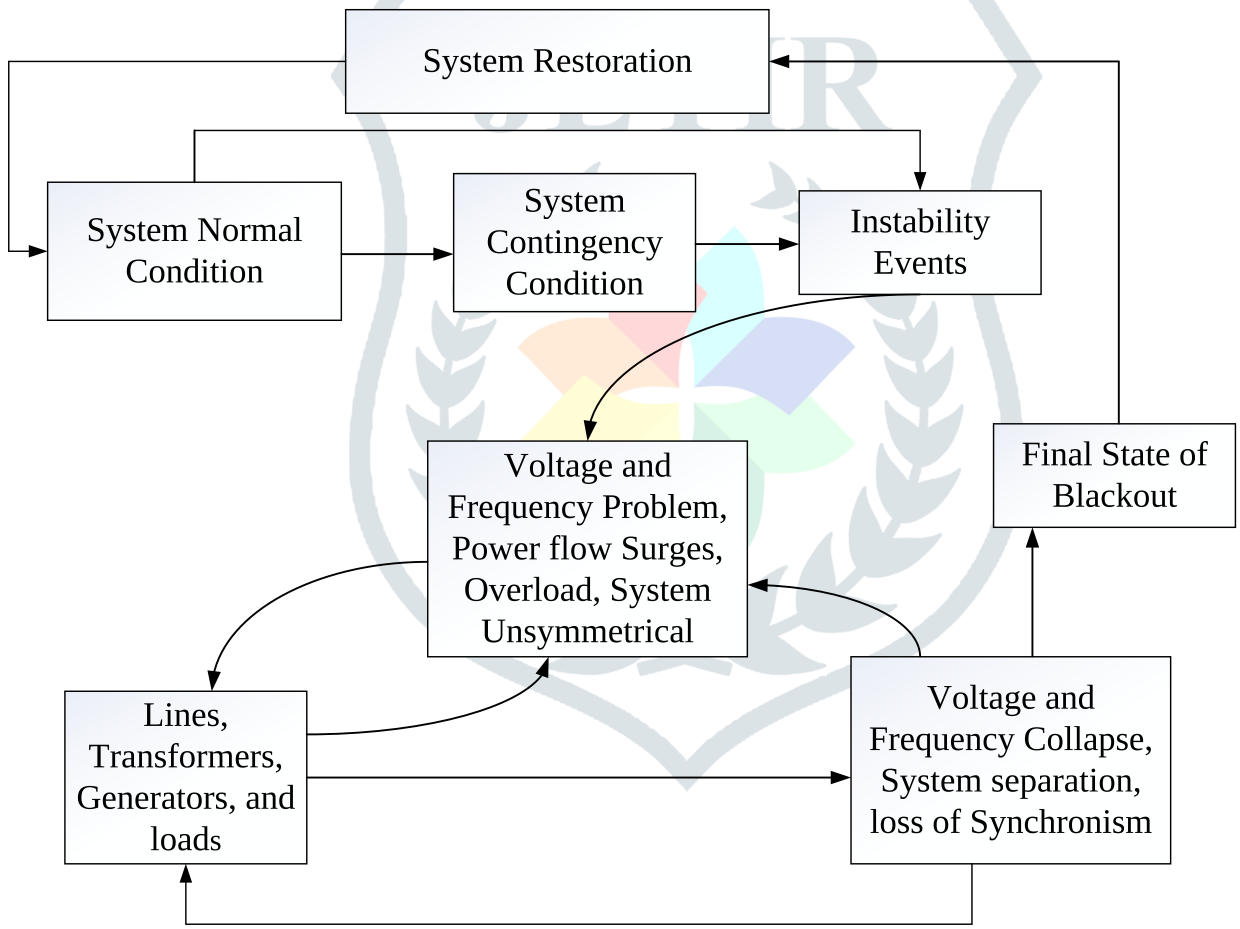

Figure 1.1 Mechanism of Blackout
Source-[Shahidehpour, 2014]

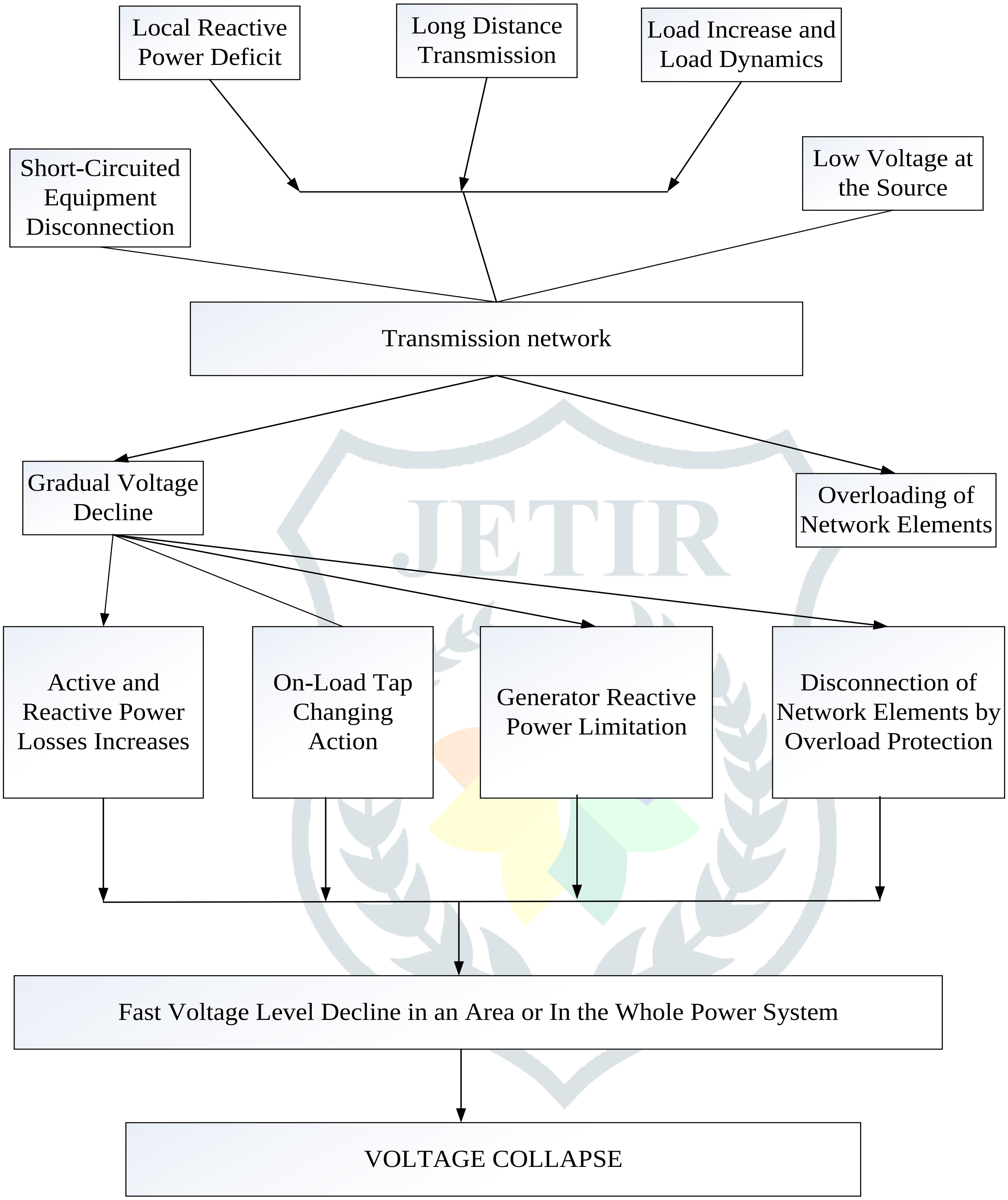

Figure 1.2 Voltage Collapse Mechanisms in Power System

Source- [Shahidehpour, 2014]

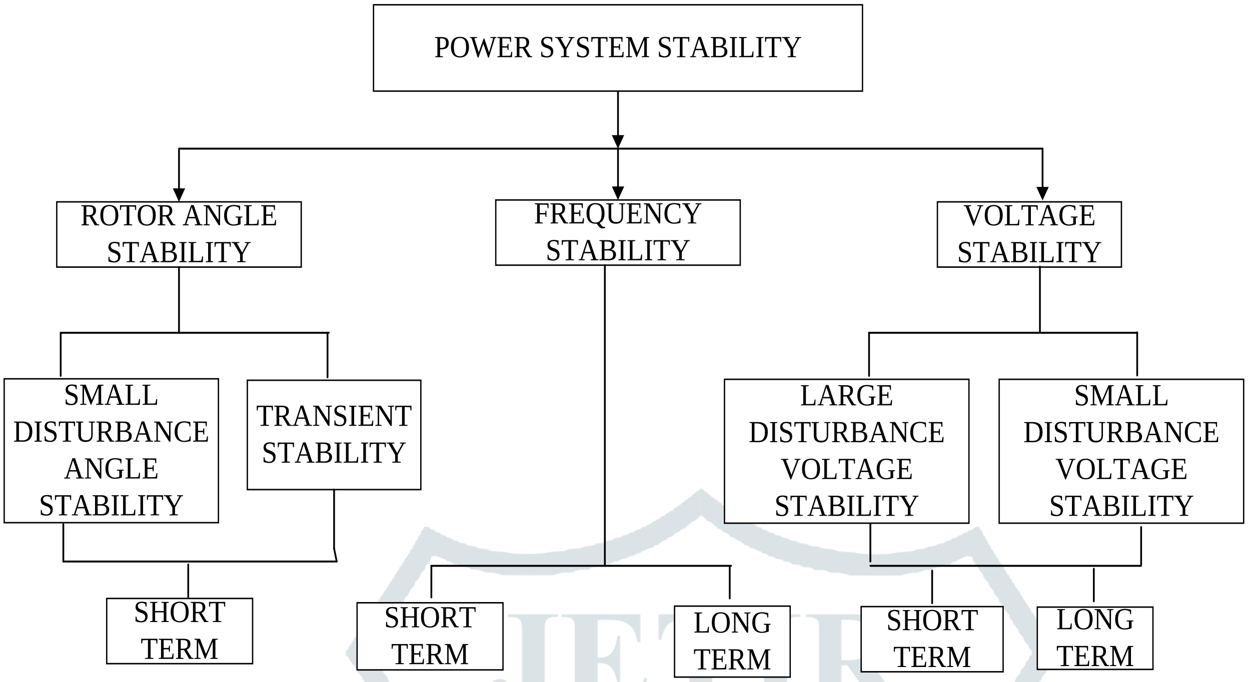

Figure 1.3 Classification of Power System Stability
Source-[Kundur, 2004]

VOLTAGE SECURITY

Voltage security can be defined as [Kothari, 2012], "*Ability of a system, not only to operate stably, but also to remain stable following credible contingencies or load perturbations*". Hitherto has been to expand the gird capacity and accommodate the exponential increase in the load without keeping the network stability and security at stake. Probably the issue was taken up for the first in [Wehenkel, 1986].An objective of security study [Wood, 1996; Wehenkel, 1989] includes:

a) Operate the system in such a way that power is delivered reliably.
b) Within constraints imposed on the system operation for reliability considerations, the system will operate most economically.
c) Appraise the systems' capability to withstand major contingencies, and
d) Suggest viable preventive or remedial corrective actions to regain the network stability.

SECURITY ASSESSMENT

The power system can be seen as a "black-box", with a specified function to serve the loads connected. It should ensure operation irrespective of operating state. To accomplish this system need to withstand any disturbance. Assessment methods are adopted in order to identify vulnerable portions of the system, estimate current or predicted state of the system and develop appropriate measures to enhance the system security. In this regard the assessment methods should be fast, accurate enough to help the operators take requisite actions beforehand. Based on the simulation type and test performed to determine stability problems, the assessment methods are divided into:

a) Steady-State methods
b) Dynamic methods

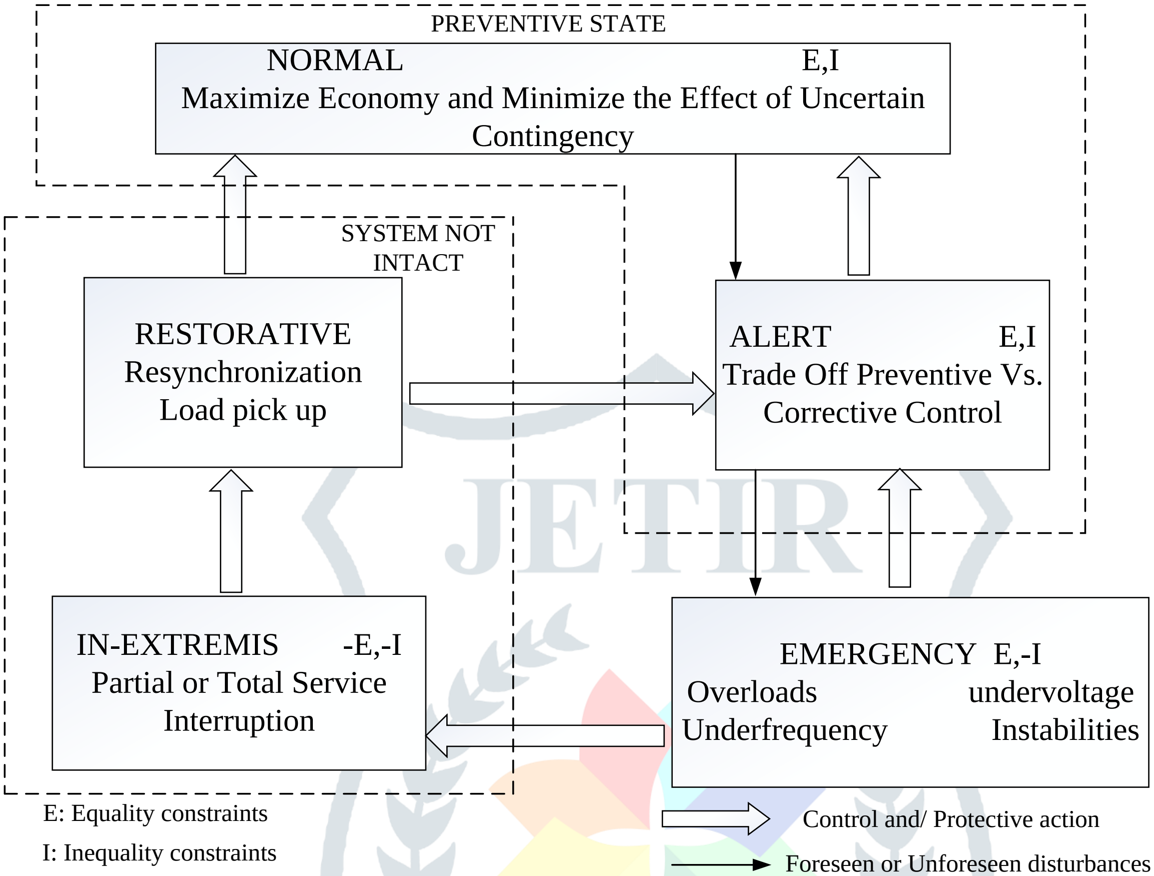

Figure 1.4 Operating States and Transition
Source- [Wehenkel, 1998]

DATAMINING IN POWER SYSTEM

Data mining approaches helps to identify the hidden underlying patterns in the system parameters, so that a model could be developed to classify the data or predict unforeseen scenarios.To analyze the available raw data, the data mining approaches has been employed. At present with fleet of sophisticated instruments available with the control center we end up with data sufficient but knowledge insufficient scenarios which paved the way for data mining in power system. First literature of its kind incorporating different aspects of data mining in power system was put forwarded by [Wehenkel, 1998]. One of the efficient tools in data mining is decision tree (DT), which has proved to be useful in data classification applications. Applications of DT in power systems were concerned with voltage security assessment [Phadke, 2001],Transient stability analysis [Wehenkel, 1986; Wehenkel, 1989], power transformer protection [Sheng, 2002], controlled islanding [Kamwa, 2012; Senroy, 2006], voltage stability [Mohammadi, 2015], voltage security [Vittal, 2010].

Schematic layout of data mining application is shown in figure 1.5. Power system parameters are traced by installed PMUs, which helps the control center to develop the database. In order to introduce data mining technique, the available database is split into two subsets namely, training/learning data and testing data. Employing learning algorithm and data mining engine model is developed. Developed model validated by employing testing data. If the model perform well it is deployed for real-time application in power system else updated for enhancing the performance.

DECISION TREE IN POWER SYSTEM

Due to merits as in [Cutsem, 1993; Phadke, 2001; Ruisheng, 2009; Vittal, 2010; Vittal, 2012; Ranjbar, 2013; Mohammadi, 2015] decision tree is employed as a decision tool in data mining. Decision tree helps to determine the relation between the measured values and the target value. DTs blend swiftly with the fast measuring capabilities of PMUs and can be employed for classification or prediction purposes. [Breiman, 1984] laid down the theoretical base for data mining and decision trees, [Wehenkel, 1986] extended the work into the field of power systems .The induction of DT is based primarily on two approaches a) TDIDT b) BFIDT.

Now advantages of decision tree can be enumerated as follows:

a) Simplicity in size
b) Reliability of diagnosis
c) Interpretability of phenomena
d) Exploring the importance of parameters
e) Ability to cope with various kinds of candidate system parameters including electrical and topological types.
f) Ability to discover and describe the underlying mechanisms of intricate phenomena

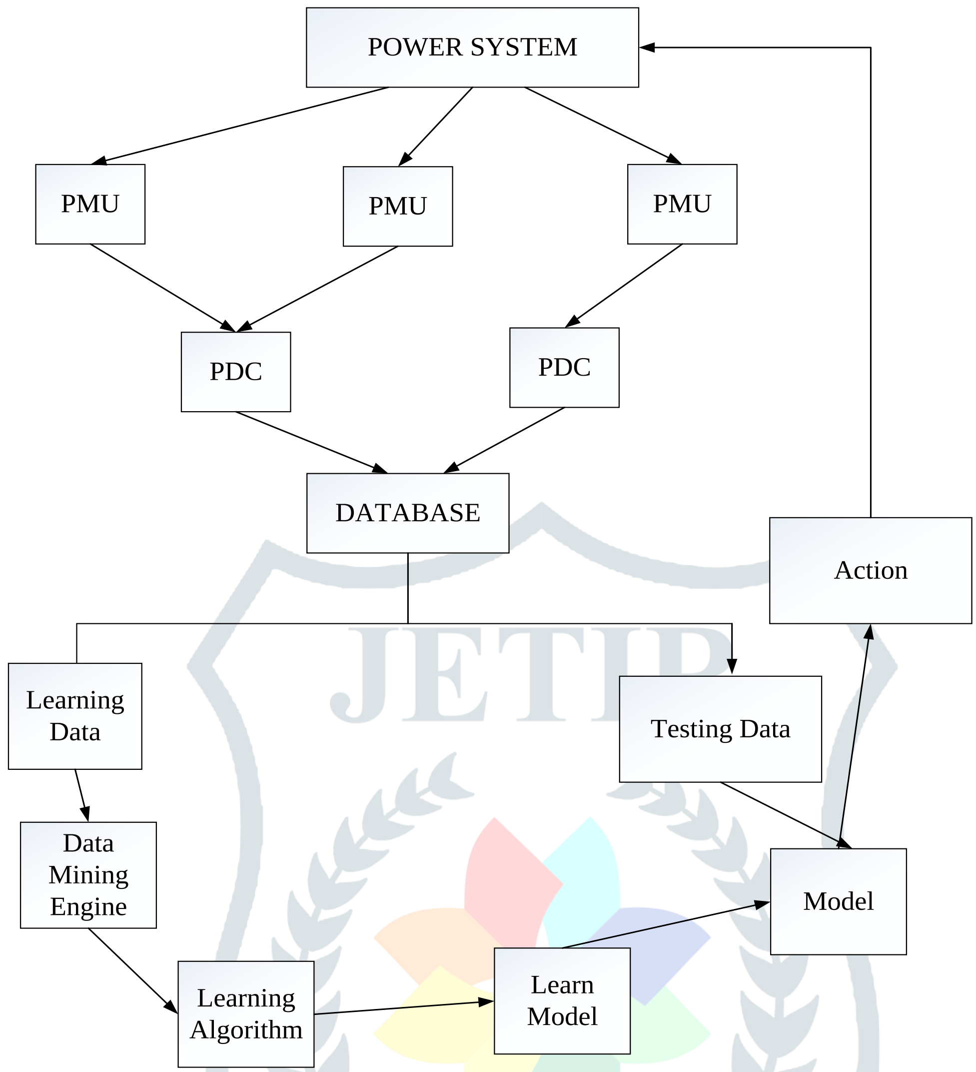

Figure 1.5 Schematic Layout of Data Mining In Power System

Improve in system security study has revealed situations with overlapping boundaries at the security decision and in course of time there has been an increase in interest of operators to deal model having more transparency and comprehensibility than earlier. This has advocated the incorporation of fuzzy rule base decision tree, resulting fuzzy decision tree (FDT) as compared to previous practice of using crisp decision tree.

CONCLUSION: In this paper it provides glimpse of the systematic and novel approach of designing fuzzy decision tree based voltage security assessment model by employing voltage stability indices, major Grid blackouts, Mechanism of black out, Voltage Collapse Mechanisms in Power System, Classification of Power System Stability, Schematic Layout of Data Mining In Power System .were discussed at an introductory level. The importance of introducing fuzzy rule into conventional DT has been discussed

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