Abstract — Power grid being a paramount system of all, has increased the need for more reliable and resilient system. Power grid has resulted in many outages lately that brought the entire industrial and domestic functionality round the globe to a stand-still. We have proposed a system that will provide look-ahead analysis of existing system. Providing a web based user interface, our system enables multi-level abstraction. The input from various parameters within the network of nodes is given to prediction model which in turn draws indications of foreseeable cascading failures. Prediction model makes use of Hybrid ARIMA-ANN model which is proved to be efficient in predicting results as compared to other existing system that implements each algorithm alone. Real time input including current, voltage, frequencies, power grid topology etc. is subjected to Hybrid model which provide, using MATLAB, statistical graph and predicted values. Thus “to predict cascading failures we have used cascading method”. This system can be deployed in existing power grid to implement process like restoration, isolation of nodes to avoid outages.

Keywords — Prediction, cascading failures, power grid, ARIMA, ANN, classification.

I. INTRODUCTION

Power systems are inevitable. With the rapid development of national economy, the power system has gradually developed into a super-large-scale system. They provide electricity to billions of individuals around the globe. Because the social structures in most countries rely on power systems, massive disruption occurs when the power grids fail to deliver energy to the consumers – transportation systems come to a halt, heating and cooling systems stop, computer systems shut down, and vital services like water and communications quickly degrade [1].

A power grid is a complex system connecting a variety of electric power generators to customers through power transmission and distribution networks across a large geographical area.

Smart grids are next generation electricity grids in which the power network and the communication network work in symphony.

In smart power grid, power grid and communication network are connected and mutually dependent. A tiny failure in either of them could trigger cascade of failures within the entire system.

The flow of electricity in the power grid is governed by the laws of physics and there are no strict capacity bounds on the lines. Instead, there is a rating threshold associated with each line, such that when the low through a line exceeds the threshold, the line heats up and eventually faults. Such an outage in turn, causes another change in the power grid, which can eventually lead to a cascading failure [2].

Recently, people all over the world suffered many outages due to cascading failures. For example, on November 1, 2014, Bangladesh suffered nationwide power outage for almost 10 hours, on Friday 21 November, 2014, South Africa experienced rolling blackouts which were implemented nationwide, and continued for the duration of the weekend. [3]

Till now, researchers have put considerable efforts in deriving models for cascading failures in power grids, with the ultimate goal of designing a reliable power-outage management system and for converting the present power grids into robust smart grids. However, detailed models of cascading failure blackouts are intractable since power grids are among the largest and most complex artificial systems. Moreover, blackouts are particularly complex phenomena as they are consequence of large number of internal and external interacting factors.

On the basis of analyzing the occurrence of cascading failures and eventually, blackouts, we propose a method which can predict subsequent failures. We use Auto-regressive Integrated Moving Average (ARIMA), which is one of the popular linear models in time series forecasting during the past three decades, after which we use Artificial Neural Networks (ANN) as a classification tool for detecting cascading failures from the predicted values.

The remainder of this paper is organized as follows. In section II, we present a brief summary about the Indian power grid scenario. In section III, the proposed system and its block diagram is explained.
The main theoretical concepts of the ARIMA model and ANN are described in section IV and V respectively. Finally, the hybrid model is explained in section VI. In section VII, we propose a further scope of the cascading failure prediction system.

II. INDIAN POWER GRID SCENARIO

Indian power grids are maintained and looked after by the Power Grid Corporation of India. In India, the regional grids situated in northern, southern, eastern, western and south eastern parts were connected together to bring up a ‘ONE NATION’-‘ONE GRID’-‘ONE FREQUENCY’ policy. Power Grid Corporation of India Ltd., takes continuous action regarding operation and maintenance to ensure compliance with prescribed standards as well as to achieve high availability of the system for uninterrupted power supply to customers [4].

A cascading failure is a failure in a system of interconnected nodes, in which the failure of one node can trigger the failure of subsequent dependent nodes, similar to a domino effect, causing a large-scale blackout. The characteristic feature of cascading failure is that a series of failures weakens the system and makes further failures increasingly more likely as the failures become widespread [5].

Figure 1: Indian power grid map

Source: http://www.wbseb.gov.in/PowerMap.aspx
Some of the major outages occurred in India due to cascading failures are described: On January 2, 2012, a fault in the transmission system in the state of Uttar Pradesh led to cascading failure throughout northern India. On July 30, 2012, due to a massive breakdown in the northern grid, there was a major power failure which affected seven north Indian states, including Delhi, Punjab, Haryana, Himachal Pradesh, Uttar Pradesh, Jammu and Kashmir, and Rajasthan. On July 31, the July 2012 India blackout, which is being called the biggest ever power failure in the world, left half of India without electricity supply [3].

Monitoring the operation of a power system in real-time and disconnection of suspected parts can help prevent a cascade. Another technique is to have pre-hand information of the occurrence of a cascading failure which is proposed further in this paper. Moreover, various load shedding strategies are also used for preventing cascading failures [6].

III. PROPOSED SYSTEM

Power systems play a very important role in the society. Because of the demerits of the existing systems, there is a need to propose a model which is able to predict the occurrence of cascading failure in future and thereby preventing the blackouts. Cascading failure in a system of interconnected parts in which the failure of a part can trigger the failure of successive parts [7]. Massive blackouts have occurred in the past since the existing system lacks real-time control ability, e.g., the very recent huge blackout happened in August, 2014, affected 2.3 lakh people in southern parts of Mumbai in India [8]. Our proposed model is a system that addresses the real time data.

The weight of each node is stored and the weight distribution is based on the topology of the network. When a node is switched off, its weight gets distributed among the other nodes which subsequently may lead to cascading failures. In this model, system parameters such as voltage, current, network topology, date and time are taken into consideration. Some noticeable deviations that could potentially weaken the systems, such as high electricity demands, heavy power flows, depressed voltages, and frequency variations, etc, could be observed using the model. Based on the observations, an analysis whether a any fault on the power line that may cause the power stations to trip.

For deploying our system to working environment, a web based interface will be generated that will ensure real time input of data providing complete status of Power Grid. The entire user interface can be made web-based. User login and registration will be provided so as to authenticate different users. Thus only Authorized users will be given controls for viewing specific data and accordingly making changes to prevent a foreseeable outage. User can navigate and use various features of our expert system. Being an online system warning and indication thus can be provided some time ahead of actual failure. Warnings can be triggered via mails of notifications on any mobile device which can bring the results to immediate notice. Corresponding reports are generated as per data provided. Xampp server is used for database management. The results generated on daily basis will be recorded and used for statistical analysis. JSP used as back-end language will provide dynamic nature to the system which is connected with MATLAB for generating visual reports and graphs.
IV. ARIMA

Time series forecasting is an important area of forecasting in which past observations of the same variable are collected and analyzed to develop a model describing the underlying relationship. One of the most important and widely used time series models is the auto-regressive integrated moving average (ARIMA) model [9]. The ARIMA model is representative of linear models and has achieved great popularity since the publication of Box Jenkins’ classic book: Time-Series Analysis: Forecasting and Control (Box and Jenkins, 1976; Zhang, 2001). The data can be collected yearly, monthly, quarterly, weekly or even daily. Data can contain any one parameter like current, voltage or power is measured.

ARIMA prediction can be carried out using a three-step process explained as follows:

A. Identification stage

In this stage, we specify the response series and identify the ARIMA model for it. Input time series is read, differencing is performed if time series is not stationary. We also compute autocorrelations, inverse autocorrelations, partial autocorrelations and cross correlations. Identification stage usually suggests more than one ARIMA models that could be fit.

B. Estimation stage

In estimation stage, we specify the ARIMA model to fit to the time series read in identification stage and to estimate the parameters of that model.

These parameters are estimated for comparing suggested models for goodness-of-fit. This stage also produces diagnostic statistics to help us judge the adequacy of the model. If these diagnostic tests indicate problems with the model, we try another model and repeat the estimation stage.

C. Forecasting stage

In forecast stage, future values of time series are forecasted and confidence intervals are generated for the forecasts from the ARIMA model produced by estimation stage. [10]

The main advantage of ARIMA forecasting is that it only requires data of the time series in question. This avoids occurrence of any problem that arises due to any multivariate models. ARIMA models are quite flexible in that they represent several types of time series [9].

V. ANN

The basic building block of an (artificial) neural network (ANN) is the neuron. ANN resembles the brain network. A neuron is a processing unit which have some (usually more than one) inputs and only one output. Roughly speaking, a neuron in an ANN is:

1. A set of input values ($x_i$) and associated weights ($w_i$)
2. A function ($g$) that sums the weights and maps the results to an output ($y$)
We use a classification model using ANN for detecting cascading failures in a given set of load data. Classification model classifies each set of data into a particular class having similar properties. ANN can learn patterns in data by mimicking the structure and learning process of neurons in the brain.

The standard ANN architecture has three layers: an input layer where features are fed in, an output layer with one neuron per class, and a hidden layer of neurons.

The inputs to the neuron are summed to give a single value, $x$. This is then input to the function, and the output of the neuron is the output of the function, $f(x)$. There are a certain weights assigned to the neuron inputs. A feature can have a large or small weight, varying the contribution it makes to the sum in any neuron. In fact, a feature can have a large weight feeding into one neuron and an almost zero weight feeding into another, meaning it has a strong influence on the first and practically none on the second.[12]

A training iteration, or epoch, is when the network has been shown every sample of training data one time. Training continues over multiple iterations, until the weights reach a steady state value, or a maximum number of iterations are reached. ANN models provide a high degree of accuracy as they are said to be universal approximators.

Initially, random weights are assigned to the neurons and output is generated. It is then compared with the actual output and error is determined. If the error is too large and undesirable, a feedback is provided and the weights are adjusted accordingly. This is known as back propagation and is a method used to train ANNs.

In our case, there is only one neuron in the output layer for detecting whether a cascading failure is possible or not. Hidden layers are decided on the basis of trial and error till accuracy is reached.

VI. THE ARIMA-ANN HYBRID

ARIMA model is the most important and widely used model for forecasting. ANNs are well known for non linear modeling capability. Hence, by using the unique properties of each of them, we propose a hybrid ARIMA-ANN model for predicting cascading failures in near-future. This hybrid model will help in improving forecasting accuracy.

For developing a hybrid model, we consider a time series as input to ARIMA. These time series will contain load information on monthly, weekly or hourly basis. ARIMA will efficiently predict the future load for the time series using the 3-stage method i.e.,

1. Identification stage
2. Estimation stage
3. Forecasting stage

These predicted values will then be given as input to ANN classifier which will detect the occurrence of cascading failures using method explained in section V. Hence, the hybrid model will look something like:

$$\text{ARIMA-ANN hybrid} = \text{ARIMA prediction} + \text{ANN classification}$$

VII. FUTURE WORK

Proposed ARIMA Model successfully predicted load consumption that the Power grid in focus will experience which can enhance strategic planning and maintaining power grid functioning. Interconnected nodes that may in near future result in blackout rendering a great economic loss can be thus prevented. The graphs and indications thus generated will be very useful in Analysis of faults that can result into severe outages. Only predicting the occurrence of cascading is not sufficient to prevent an outage, the results thus generated must be conveyed to utility authorities that can take necessary preventive measures to stop could be occurring blackout. We have used email to inform relevant staff. Our system can further use variant ICT tools to spread the warning thus generated.

In a power, common reason of failure causing an outage is single point failure. A single node fails due to overload or other malfunctioning reasons which in turn causes other dependent nodes to fail as well. Thus, the cause is a single node, transmission line, etc. and other nodes are working in normal range. Some nodes in system also operate in a lower range than that they can handle. If load of faulty node can be redistributed to such nodes might prevent catastrophic loss.
Our system provides report of such nodes that can be further analyzed and used to prevent an outage. Feedbacks can be recorded from experts and thus training can be improved using ANN to implement dynamic redistribution to the grid.

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