Grid Solutions

LOOK AHEAD FORECASTING: THE ART AND SCIENCE OF PREDICTING NEAR-TERM GRID RELIABILITY TRENDS

Whitepaper

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INTRODUCTION

Power flow analysis is the most critical of all network calculations as it is concerned with the network performance in normal and abnormal operating conditions. It is performed to investigate the magnitude and phase angle of the voltage at each bus as well as the real and reactive power flows in system components.

Power flow analysis has a great importance in future expansion planning, as a starting point in stability studies and in determining the best economical operation for existing systems. Power flow results are also very valuable for setting the proper protection devices to ensure system security.

Most power systems are designed with sufficient redundancy to withstand all major failure events. Contingency analysis is one of the key components in today's modern energy management systems1 such as GE Vernova's PowerOn™ Reliance. For the purpose of quickly estimating system stability directly following outages, the study of contingency analysis involves performing efficient calculations of system performance from a simplified set of system conditions.

Conventionally, power flow analysis is run against current system conditions to understand line flows and bus voltages in the system to assist in assessing whether the system is experiencing any limit violations, either in terms of flows and/or voltages. Similarly, contingency analysis is performed to determine the effect of outages of certain transmission devices on the system with current operating conditions.

This paper discusses the PowerOn Reliance approach to running power flows and contingency analysis ahead of time using the forecasted values of load, interchange and generation obtained from various external sources. With this approach, violations related to power flows and each contingency can be determined in advance and planned for accordingly. This results in more effective maintenance of the power grid.

This paper also discusses the representation of results obtained from the above analysis. Violated voltages and branch flows for selected buses and branches are illustrated in 2D and 3D graphs created from the analysis data. These graphs represent the variation of violated voltages and branch flows for a 24-hour period in a day ahead scenario for selected buses and branches. These representations are possible for both power flow and contingency analysis output. This graphically intuitive interface allows operators to easily analyze the results for a 24-hour period to determine the critical buses and branches with the most security violations in the system.

POWERON RELIANCE LOOK AHEAD FORECASTING ANALYSIS APPLICATION

A. IMPORTANCE

In a modern day interconnected power system network, predicting the future state of the system is very much needed in order to prepare for any abnormalities. Power system applications such as power flow analysis and contingency analysis work on the current operating state of the network obtained from the state estimation process, hence these applications can't be taken as a base for assessing the future state of the network. The look ahead forecast analysis (LAFA) module developed by GE Vernova gives a view into the future state of the network with 2D and 3D graphic visualizations.

There are two important operating states for which operators need complete information 24 hours in advance (look ahead). One is the current operating state (power flows); the other is the contingency state of the power system.

Conventionally, the results of contingency analysis such as the number of real and reactive power violations are displayed per contingency for all the contingency cases defined; as a result, users struggle to pinpoint their area of interest in a timely fashion. If users want to compare the effects of a contingency on a particular part of a network with multiple schedules, it takes significant time to navigate between various displays with results related to both time intervals.

The PowerOn Reliance LAFA module application explained in this paper, however, filters and consolidates the data required to undertake analysis on multiple time intervals and contingencies. LAFA facilitates visualizing bus and branch violations in 2D and 3D graphs for a 24-hour period of time ahead of the execution time. The user can select any element of interest and identify the violations on that element for the selected contingency case and time period. These LAFA features give users the flexibility to choose any part of the network which is of interest and assess the condition of the selected elements over a period of time for a predefined list of contingencies. LAFA allows this to be completed in a single action versus the multiple set up and configuration actions required under a conventional system.

In summary, the salient features of LAFA are as follows:

- Execution of power flows and contingency analyses for a period of 24 hours (day ahead)
- Presentation of the number of active and reactive violations for base case and contingency case, for each hour along with 2D and 3D graphs depicting the bus and branch violations
- Provision to select any network element to see the violations on that element ahead of time, for the base case and for a selected contingency case
- Listing of the most severe violations (bus and branch) among the list of contingencies defined for any selected period of time
- Exporting results into CIM format

With the above mentioned features, the LAFA module gives the control center operator a clear picture of violations in the network for future operating states, providing the operator enough time to plan actions to mitigate the violations which may otherwise make the system fragile.

B. DATA INITIALIZATION

Inputs for analysis can be obtained from a load forecast, unit commitment, interchange schedules and power flow schedules already present in the PowerOn Reliance EMS system. LAFA is capable of running power flow and contingency analysis for a 24-hour period in a day ahead scenario with a minimum of a 30-minute resolution.

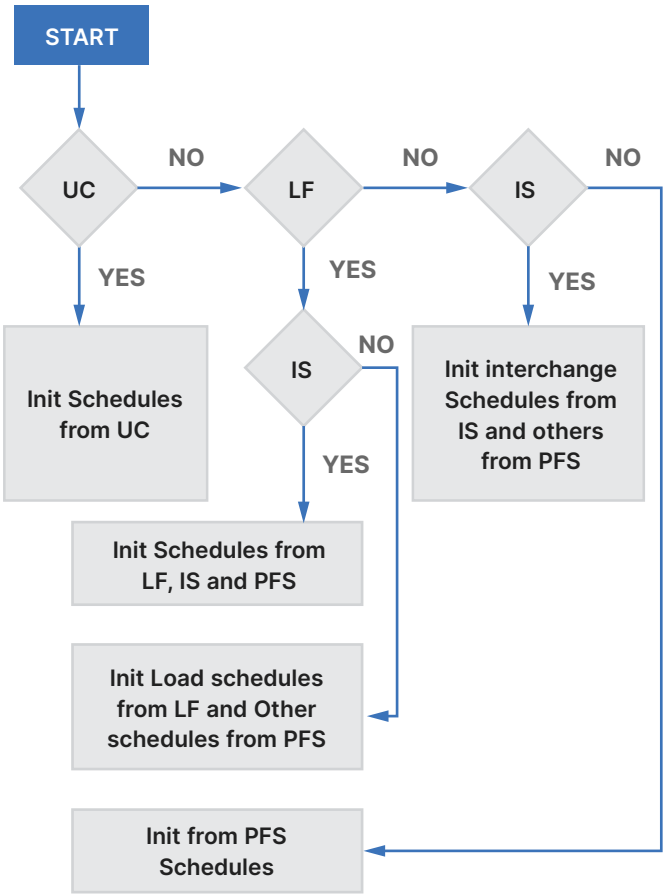


Figure 1: Logic used to determine which inputs should be used to run the power flow and contingency analysis.

1. Sources of Data

- **Unit Commitment (UC):** This module calculates the generator operating plan for the next seven days with a 24-hour resolution. Inputs include forecasted load values.
- **Load Forecast (LF):** This module calculates the forecasted load values for the next seven days with a 24-hour resolution. Inputs to this module include historical weather data, historical load data and forecasted weather data.
- **Interchange Schedules (IS):** This module calculates the tie-line exchanges between two different companies with a 24-hour resolution. Schedules are agreed to by both companies.
- **Power Flow Schedules (PFS):** These schedules are needed for the power flow to run. They typically include generator MWs, load MWs, bus voltages and transformer taps.

2. Data Initialization Priority Hierarchy

If the UC module is present in the system, then the data required for the initialization can be inherited. If this module is not present, then the LF module can initialize the load data and the IS module can initialize the interchange data.

If none of the modules are present in the EMS system, then the power flow schedules can be used to initialize the data.

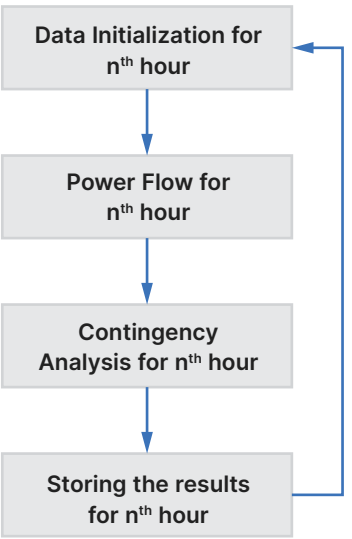


Figure 2: Logic flow outlines the looping process used, in regular intervals, to complete the power flow and contingency analysis.

3. Data Initialization Methodology

First, a check is carried out to determine whether the system is configured with UC. If so, then the load generating schedules and interchange schedules will be taken from this module.

If the system is not configured with UC, a check is made to see whether LF and IS are configured. If both are configured, then the load schedules are taken from the LF module, interchange schedules are taken from the IS module, and generation schedules are taken from power flow schedules. If the system has the LF module and there is no IS module, then the interchange schedules are taken from power flow schedules.

If none of the systems are available, the application takes the required schedules from power flow schedules.

C. PROCESS

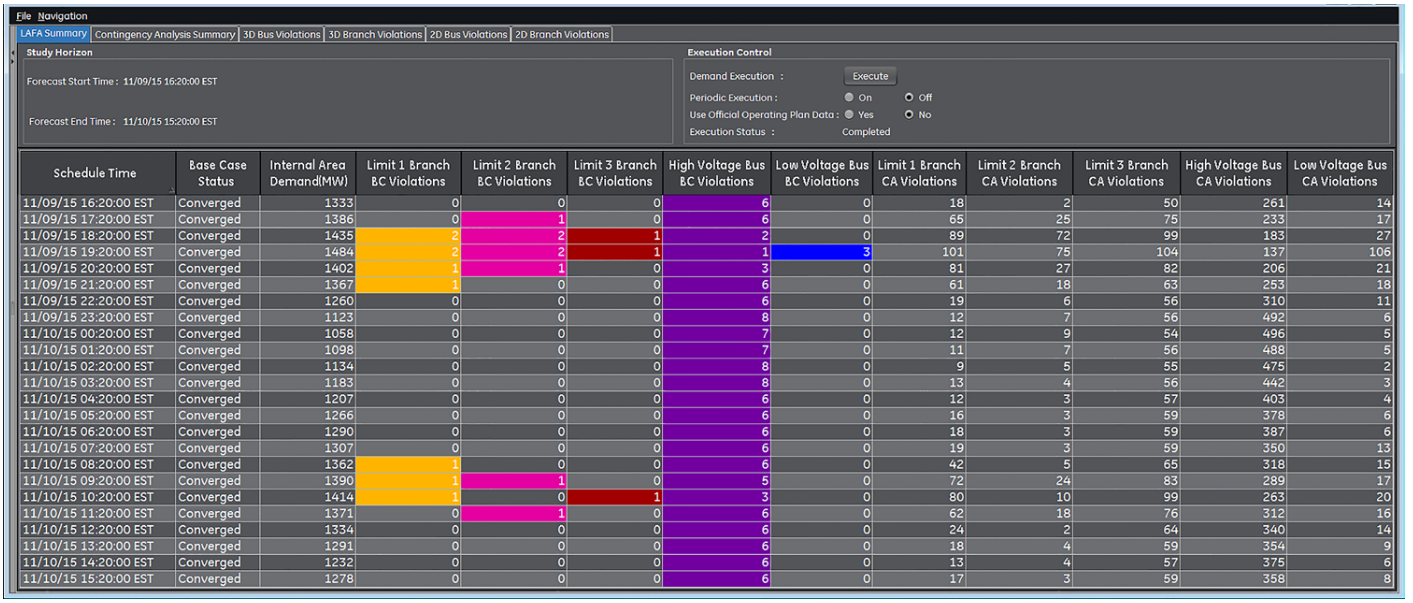
Once data initialization is complete, power flow is run to simulate a 24-hour period scenario with a minimum of 30-minute resolution. After that, contingency analysis is run with all configured contingencies on the system. The results are stored in binary files for further analysis.

The LAFA application has the ability to divide the processing among multiple processors for faster performance, and can be run either manually or periodically at the end of each hour for the subsequent 24 hours.

RESULTS

Results from PowerOn Reliance's LAFA can be visualized using tabular 3D and 2D graphs. In tabular format, results are consolidated for each hour. The tabular format displays the number of voltage and branch violations during power flow and contingency analysis.

Users can configure a predefined set of buses and branches to view the resultant violations. This allows the user to view the buses/branches violations in the same graphical positions from run to run, providing a better feel as to how the voltages/flows for areas of concern are changing across intervals.


File Navigation

LAFA Summary | Contingency Analysis Summary | 3D Bus Violations | 3D Branch Violations | 2D Bus Violations | 2D Branch Violations

Study Horizon

Forecast Start Time : 11/09/15 16:20:00 EST

Forecast End Time : 11/10/15 15:20:00 EST

Execution Control

Demand Execution : Execute

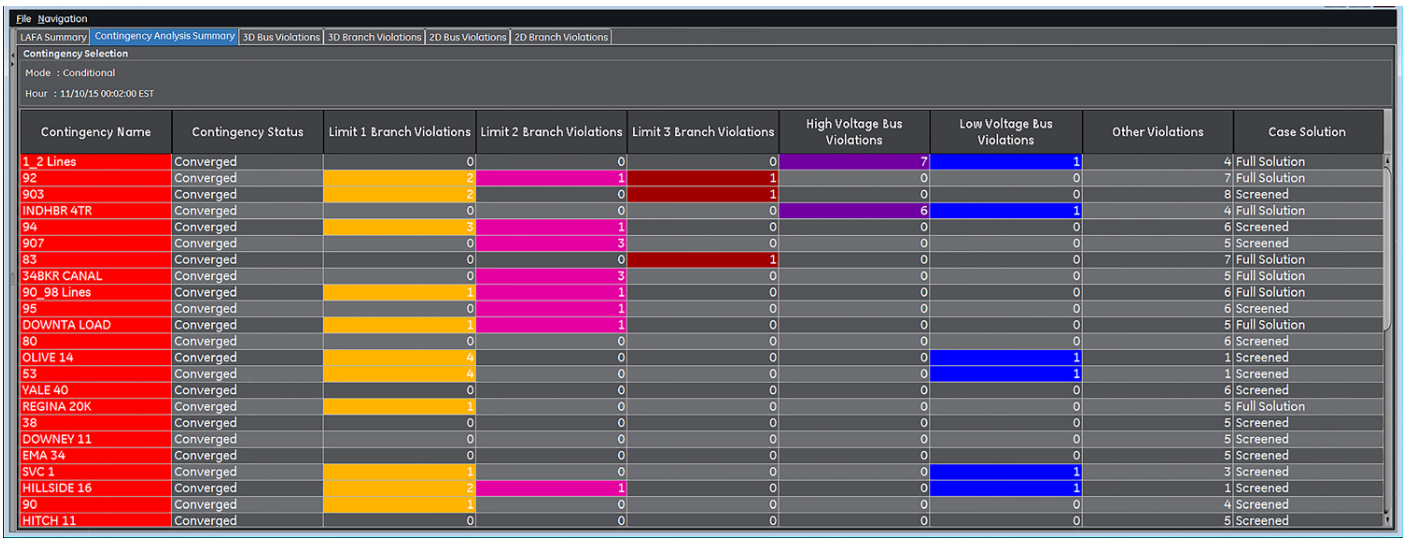
Periodic Execution : On Off

Use Official Operating Plan Data : Yes No

Execution Status : Completed

Schedule Time	Base Case Status	Internal Area Demand(MW)	Limit 1 Branch BC Violations	Limit 2 Branch BC Violations	Limit 3 Branch BC Violations	High Voltage Bus BC Violations	Low Voltage Bus BC Violations	Limit 1 Branch CA Violations	Limit 2 Branch CA Violations	Limit 3 Branch CA Violations	High Voltage Bus CA Violations	Low Voltage Bus CA Violations
11/09/15 16:20:00 EST	Converged	1333	0	0	0	6	0	18	2	50	261	14
11/09/15 17:20:00 EST	Converged	1386	0	1	0	6	0	65	25	75	233	17
11/09/15 18:20:00 EST	Converged	1435	2	2	1	2	0	89	72	99	183	27
11/09/15 19:20:00 EST	Converged	1484	2	2	1	1	3	101	75	104	137	106
11/09/15 20:20:00 EST	Converged	1402	1	1	0	3	0	81	27	82	206	21
11/09/15 21:20:00 EST	Converged	1367	1	0	0	6	0	61	18	63	253	18
11/09/15 22:20:00 EST	Converged	1260	0	0	0	6	0	19	6	56	310	11
11/09/15 23:20:00 EST	Converged	1123	0	0	0	8	0	12	7	56	492	6
11/10/15 00:20:00 EST	Converged	1058	0	0	0	7	0	12	9	54	496	5
11/10/15 01:20:00 EST	Converged	1098	0	0	0	7	0	11	7	56	488	5
11/10/15 02:20:00 EST	Converged	1134	0	0	0	8	0	9	5	55	475	2
11/10/15 03:20:00 EST	Converged	1183	0	0	0	8	0	13	4	56	442	3
11/10/15 04:20:00 EST	Converged	1207	0	0	0	6	0	12	3	57	403	4
11/10/15 05:20:00 EST	Converged	1266	0	0	0	6	0	16	3	59	378	6
11/10/15 06:20:00 EST	Converged	1290	0	0	0	6	0	18	3	59	387	6
11/10/15 07:20:00 EST	Converged	1307	0	0	0	6	0	19	3	59	350	13
11/10/15 08:20:00 EST	Converged	1362	1	0	0	6	0	42	5	65	318	15
11/10/15 09:20:00 EST	Converged	1390	1	1	0	5	0	72	24	83	289	17
11/10/15 10:20:00 EST	Converged	1414	1	0	1	3	0	80	10	99	263	20
11/10/15 11:20:00 EST	Converged	1371	0	1	0	6	0	62	18	76	312	16
11/10/15 12:20:00 EST	Converged	1334	0	0	0	6	0	24	2	64	340	14
11/10/15 13:20:00 EST	Converged	1291	0	0	0	6	0	18	4	59	354	9
11/10/15 14:20:00 EST	Converged	1232	0	0	0	6	0	13	4	57	375	6
11/10/15 15:20:00 EST	Converged	1278	0	0	0	6	0	17	3	59	358	8

Figure 3: Hourly tabular summary of voltage and branch violations during power flow and contingency analysis .


File Navigation

LAFA Summary | Contingency Analysis Summary | 3D Bus Violations | 3D Branch Violations | 2D Bus Violations | 2D Branch Violations

Contingency Selection

Mode : Conditional

Hour : 11/10/15 00:02:00 EST

Contingency Name	Contingency Status	Limit 1 Branch Violations	Limit 2 Branch Violations	Limit 3 Branch Violations	High Voltage Bus Violations	Low Voltage Bus Violations	Other Violations	Case Solution
1_2 Lines	Converged	0	0	0	7	1	4	Full Solution
92	Converged	2	1	1	0	0	7	Full Solution
903	Converged	2	0	1	0	0	8	Screened
INDHBR 4TR	Converged	0	0	0	6	1	4	Full Solution
94	Converged	3	1	0	0	0	6	Screened
907	Converged	0	3	0	0	0	5	Screened
83	Converged	0	0	1	0	0	7	Full Solution
34BKR CANAL	Converged	0	3	0	0	0	5	Full Solution
90_98 Lines	Converged	1	1	0	0	0	6	Full Solution
95	Converged	0	1	0	0	0	6	Screened
DOWNTA LOAD	Converged	1	1	0	0	0	5	Full Solution
80	Converged	0	0	0	0	0	6	Screened
OLIVE 14	Converged	4	0	0	0	1	1	Screened
53	Converged	4	0	0	0	1	1	Screened
YALE 40	Converged	0	0	0	0	0	6	Screened
REGINA 20K	Converged	1	0	0	0	0	5	Full Solution
38	Converged	0	0	0	0	0	5	Screened
DOWNEY 11	Converged	0	0	0	0	0	5	Screened
EMA 34	Converged	0	0	0	0	0	5	Screened
SVC 1	Converged	1	0	0	0	1	3	Screened
HILLSIDE 16	Converged	2	1	0	0	1	1	Screened
90	Converged	1	0	0	0	0	4	Screened
HITCH 11	Converged	0	0	0	0	0	5	Screened

Figure 4: Tabular representation, post analysis of branch and bus violations on a per contingency basis.

Users can select specific buses to view violated voltage variations - and branches to see the variation of violated flows – for the next 24 hours in a 3D graph. Users can also select a particular contingency to view how the voltages and branch flows vary due to the contingency. Users can view the most severe voltage or branch violations for a particular hour using a 2D graph. The application is capable of showing in a 2D graph how a particular contingency affects the violations for a particular hour.

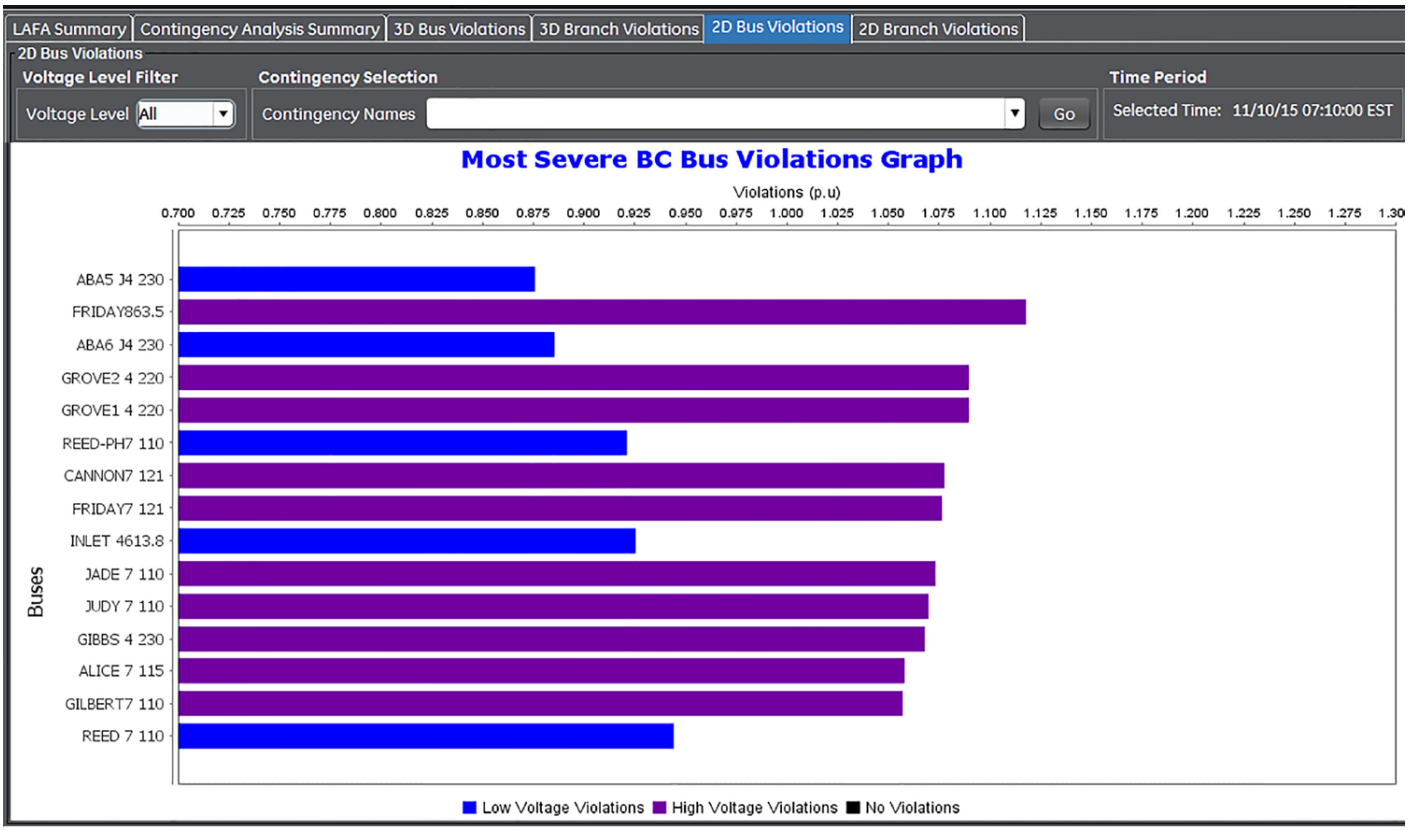


Figure 5: 2D graph provides clear indication of the most severe bus violations identified during analysis.

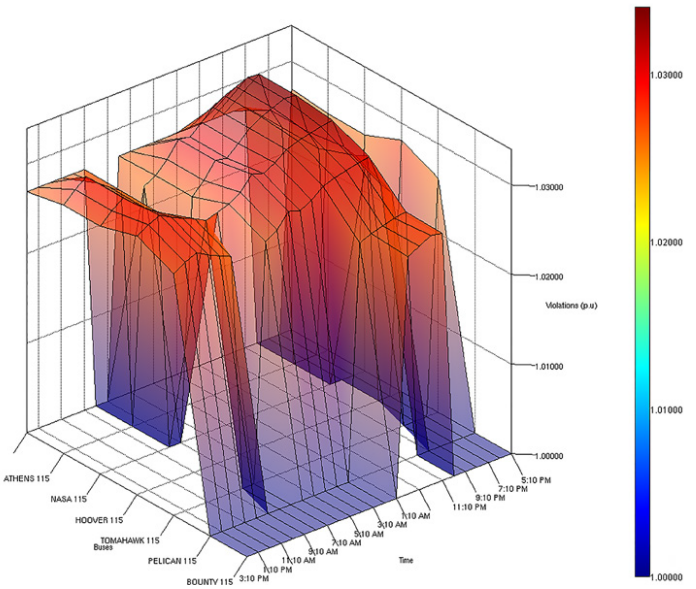


Figure 6: Advanced visualization capabilities help identify voltage variations for selected buses using integrated 3D tools.

CONCLUSION

The PowerOn Reliance LAFA module offers an effective solution to the control center operator's everyday challenge of assessing the future state of network. It is a critical tool in detecting the deviations from normal bus voltages and branch flows for a period of 24 hours in a day ahead scenario.

Contingency analysis can be run ahead of time with forecasted load and interchange data so that proper planning can be carried out to reduce the effect of contingency on the grid. LAFA results are presented in 2D and 3D graphs in terms of the most severe violations as well as the violations on any selected network element. These features enable the operator to plan accordingly to mitigate the most severe violations to protect the network from black outs. A converged solution from the LAFA module can be exported to CIM format, to enable exchange with other utilities or other software modules provided by different vendors.

REFERENCES

Veenavati jagadishprasad Mishra, Manisha D. Khardenvis, "Contingency Analysis of Power System," International Conference on Emerging Frontiers in Technology for Rural Area (EFITRA) 2012, Proceedings published in International Journal of Computer Applications™ (IJCA).

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