Grid Monitoring Tool- A Case Study of ERLDC, Kolkata

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***Abstract*—To improve the response time of the system operator, a robust monitoring system is recommended. Design of such system is done so as to impart additional intelligence to the conventional monitoring system by creating logical analytics, using abnormality / limit violation of important parameters such as frequency, flow gate limits etc. or using combination of two or more such parameters. Further, the output of such logical tests / analytics may be monitored periodically and alerts may be generated for violation of preset values of any of the tests. Such a system may be utilized to alert relevant functional groups other than grid operator viz. reliability coordinator, market operation group etc.**

Keywords—Grid Monitoring Tool, ERLDC, UFR, df/dt, CEA, Grid Operating Conditions, A2P messaging

I. INTRODUCTION

Topology of power systems is defined by interconnections among power system components such as generators, power transformers, bus bars, transmission lines and loads. The interconnected infrastructure is called power system network. The topology of the power network at any point of time is obtained by determining status of the switching devices responsible for maintaining the continuity within the network. Such devices are called circuit breakers (CBs), and they are used to connect or disconnect any power system component to/from the rest of the network. Real-time monitoring of the power system is typically done through Remote Terminal Units (RTUs) installed at various sub-stations and power stations. The RTUs are wired to the CB auxiliary contacts in the substation switchyard, and detect changes in the CB status. These changes are in turn reported to the System Control Centre through a Supervisory Control and Data Acquisition (SCADA) system.

Power system security is the ability of the system to withstand contingencies. Power systems are continuously subject to disturbances covering a wide range of conditions. Typical examples of disturbance conditions are sudden changes in load, loss of one or more transmission lines, faults, modifications in the system configuration, equipment outages and generator failures. System security is an instantaneous condition. It is a function of time and of the robustness of the system with respect to imminent disturbances. The working definition of security is in terms of the system state. Which is a compact description used to summarize key information about the system. Once the system state is known, it can be used to determine any variable of interest.

State of a power system is typically classified as being one of four possible types – normal, alert, emergency and restorative. A normal state is characterized by having all equality and inequality constraints satisfied. The system is capable of withstanding any single contingency in the normal state. However if generation reserve fall below a certain threshold or load increases beyond some limit, the system is said to enter the alert state, although the equality and inequality constraints are still met. Preventive action should be taken to steer the system out of the alert state. An emergency state is one in which one or more of the physical operating limits are violated (e.g., line overloads, over/under voltages, over/under frequency). A restorative state is one where one or more of the loads are not met -- partial or total blackout, but the partial system is operating in a normal state. During alert as well as emergency condition, system operator should take corrective action so that system is brought back to its normal operating condition. Normally automatic action of defense mechanisms takes place during emergency condition like operation of UFR, df/dt, SPS.

II. EMERGENCY OPERATING CONDITIONS

In normal operation of the grid with all elements available, parameters like voltages, line loadings, and frequency should remain within permissible limits. The grid may however be subjected to disturbances and it is generally planned such that after a probable disturbance i.e. loss of an element ('N-1' or single contingency condition), all the system parameters like voltages, line loadings, frequency remain within permissible normal limits.

However, after suffering one contingency, the grid is still vulnerable to experience a second contingency, though less probable ('N-1-1'), wherein some of the equipment may be loaded up to their emergency limits. Typical normal & emergency voltage limits of EHV

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transmission system and loading limits of overhead lines are shown in table 1(a) & 1(b) which have been taken from CEA Transmission Planning Criteria manual 2013. To bring the system parameters back within their normal limits, load shedding/re-scheduling of generation may have to be applied either manually or through automatic system protection schemes (SPS). Such measures shall generally be applied within one (1) hour after the disturbance. [As per IEGC Cl. 6.5.18 2nd. amendment 2014]

TABLE 1(A). EMERGENCY VOLTAGE LIMITS

Voltages (KVrms)				
Nominal	Normal Rating		Emergency Rating	
	Maximum	Minimum	Maximum	Minimum
765	800	728	800	713
400	420	380	420	372
230	245	207	245	202

TABLE 1(B). THERMAL LOADING LIMITS OF T/L

Thermal Loading of Transmission Lines *(at 45 deg. Ambient temp & 75 deg. Conductor Temp.)*		
Conductor Type	Thermal Loading (MVA)	Emergency Loading (MVA) 110% of Thermal Loading
400KV ACSR Moose	873	961
400KV AAAC	839	923
220KV ACSR Zebra	213	234
220KV AAAC	212	233

III. GRID MONITORING TOOL

There have been instances of some unpredictable combination of operating conditions, faults, forced outages, or other disturbances due to which the system has already transitioned to an alert state. Any subsequent contingency may trigger cascade tripping, eventually leading to system split-ups and/or a partial or complete blackout. During the emergency condition, response time of system operator plays a vital role. Moreover, it is important that the grid operator is adequately equipped to capture the emergency scenarios and near miss conditions upfront.

To improve the response time of the system operator, a robust monitoring system is recommended. Design of such system is done so as to impart additional intelligence to the conventional monitoring system by creating logical analytics, using abnormality / limit violation of important parameters such as frequency, flow gate limits etc. or using combination of two or more such parameters. Further, the output of such logical tests / analytics may be monitored periodically and alerts may be generated for violation of preset values of any of the tests. Such a system may be utilized to provide alert relevant functional groups other than grid operator viz. reliability coordinator, market operation group etc.

Objectives of a Grid Monitoring Tool are as follows:-

a) Situational awareness of Reliability Coordinators and Market Operation Dept.

b) Quick response from Reliability Coordinators.

c) Control room monitoring during emergency condition (New layer of monitoring system).

d) Control room monitoring outside the control room 24X7.

It may be appreciated that the design requirement of such system not only requires to include suitable intelligence in monitoring the parameter to automatically ascertain emergency situations but also to suitably transmit alert / alarm to relevant functional groups within control room or outside. Schematic of a monitoring system shown in Figure1.

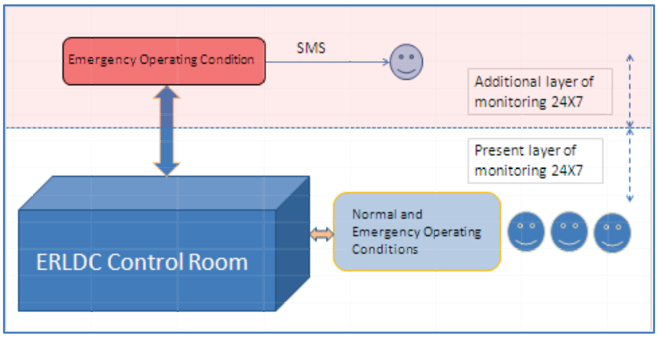

Fig.1 Grid Monitoring Tool

IV. WORKING OF SYSTEM MONITORING TOOL

To achieve the objective of the Grid Monitoring Tool it is important that the additional layer over and above the conventional layer of grid monitoring (i.e. the control room real time monitoring system) created is suitably selected and filtered information is passed on to the next level so that alarm is generated during emergencies only. The alert messages can be triggered at the time of need to sensitize concerned operators, reliability coordinators; market operators etc. so than no emergency situation remains unnoticed and/or unattended. This will necessarily ensure better sensitivity in the functional groups of the additional layer.

Accordingly, set of logical tests to be performed considering one or a group of various important grid parameters, to check violation and its permissible limits needs to be determined considering the system constraints, in order to ascertain the state of the grid thereof. These tests are also required to be periodically renewed with continuous expansion and change in the

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power system. Otherwise, some of the conditions being tested today may become infructuous at a future date and new conditions may develop with changing scenario.

A snapshot of various such parameters and the limits considered for ascertaining normal / emergency situation is listed in Table 2.

TABLE 2. EMERGENCY BAND SELECTION

System Parameters	Normal Operating Band	Emergency Band
1)Frequency	49.9-50.05 Hz	<49.9-50.05Hz<
2)Voltage	380-420 KV	<375-435KV<
3)400KV Lines overloading	<515MW	515MW<
4)Over drawl/Under drawl	150MW or 12% of Sch	(+/-) 300MW
5)Tripping of 400KV lines	Change in status	Change in status
6)Tripping of Gen units	Change in status	Change in status
7)dP/dt	Step Change	Step Change
8)Inter-Regional TTC	IR flow > ATC	IR flow > TTC

After deciding the parameters and their limits, periodic and continuous monitoring of the selected parameters is needed. For this purpose the conventional SCADA data or PMU data can be used. Each set of parameters values (in a specific instance) may be compared with the limiting criteria and on violation alarm may be annunciated. The alarm may be suitably formatted to have meaningful information and the target functional group for each set of violation may also be defined separately.

Suitable services may be integrated with this monitoring system to transmit the generated alarm to the desired groups. For such purpose various third party application and communication system may be utilised. Web SMS (Short Message Service) service is one of the most popular and widely used service for such applications.

V. SMS SERVICE FOR TEXT MESSAGES

SMS is a stateless communication protocol in which every SMS message is considered entirely independent of other messages. Further, Application-To-Person (A2P) messaging is a type of SMS sent from a subscriber to an application or sent from an application to a subscriber.

Enterprise applications using SMS as a data bearer require that session management be maintained external to the protocol. Transmission of short messages between the SMSC (short message service center) and the handset is done whenever using the Mobile Application Part (MAP) of the SS7 protocol.

SMS gateway providers facilitate SMS traffic between businesses and mobile subscribers, including mission-critical messages, SMS for enterprises, content delivery, and entertainment services involving SMS. Message Service Centers communicate with the Public Land Mobile Network (PLMN) or PSTN via Interworking and Gateway MSCs. Subscriber-originated messages are transported from a handset to a service center, and may be destined for mobile users, subscribers on a fixed network, or Value-Added Service Providers (VASPs), also known as application-terminated. Subscriber-terminated messages are transported from the service center to the destination handset, and may originate from mobile users, from fixed network subscribers, or from other sources such as VASPs. The VASPs providing the content submits the message to the mobile operator's SMSC(s) using an TCP/IP protocol such as the short message peer-to-peer protocol (SMPP) or the External Machine Interface (EMI). The SMSC delivers the text using the normal Mobile Terminated delivery procedure.

VI. IMPLEMENTATION AT ERLDC, POSOCO

ERLDC (Eastern Regional Load Despatch Centre) is the apex body to ensure integrated operation of the power system in the Eastern Region of India. ERLDC system operators are equipped with State-of-the-art conventional SCADA system for grid monitoring. In addition, a typical Grid Monitoring Tool has been deployed in line with the above philosophy using SCADA data.

The system continuously monitors various pre-defined grid parameters using SCADA data at 1 minute interval and performs necessary logical tests based on coded algorithm. Further, the system compares the values with preset emergency limits to ascertain system state.

In case of a limit violation, the system automatically triggers alarm using state-changing Booleans. The alarm is further transmitted to the next module to generate text messages depending upon the emergency conditions and parameters. For this purpose the violating parameters are also passed on to the next module using global variables.

The following parameters / violations are presently being monitored through this system:

a) *Frequency violation beyond emergency band*
b) *Tripping of / Overloading beyond emergency limit of major Transmission Line affecting flow gate*
c) *ATC (Available Transfer Capability) and TTC (Total Transfer Capacity) violation.*

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d) Violation beyond emergency limits of critical bus voltages

e) Deviations of various entities with respect to their schedules within ER beyond a pre-specified limit.

A user front end has been created to pre-define the emergency limits depending on grid contingencies as well as to add / edit new elements or additional parameters. Also the text message against violation of each type of parameter can be pre-defined using the front end. The intended user's name and mobile number is also pre-populated and can be appended as and when required.

Once the Grid Monitoring Tool triggers any alarm, the application passes on the trigger along with the necessary information such as violating parameters, SMS text, relevant user details etc. to the next module to generate SMS alerts accordingly. Further, SMS alerts are sent to respective users using A2P and third party VASPs.

The SMS application includes a feature to combine multiple text for more than one violations. The Grid Monitoring Tool triggers different Booleans depending on number of parameters violating limits. Accordingly, multiple events of violations are created with single text message combining all the messages. The message is then further transmitted to the desired users. This ensures single snap information to the end user for any emergency scenario.

As the Grid Monitoring Tool monitors SCADA data and compares with emergency limits in each 1 minute time interval, to filter multiple SMS annunciation for same violation in each minute (due to persistence of the violation for longer duration) a timestamp of the last violation time is maintained with value of consecutive minute of violation. Further, the application also has an inbuilt feature of reminder SMS in case of non-corrections within pre-defined time limit viz. if any violation persists for more than a pre-set time (say 15 or 30 minutes) a repeat SMS for the same violation shall be sent as reminder indicating the duration of persistence.

The system also keeps a log of all the SMS sent thereby creating a log of each type of violations and emergency situations happening in the grid from grid operation as well as market operation perspective. The log can be more prudently used in system study and future planning.

VII. EXPERIENCE GAINED AND LIMITATIONS

As a direct impact, the monitoring system undoubtedly has improved awareness regarding real time grid scenario among functional groups beyond control room grid operators. Situational awareness of the reliability coordinators has been enhanced with no major / minor near-miss scenarios remaining un-noticed.

Analysis of the logs created on each emergency / violations also give a clear idea of repetitiveness of any typical violation thereby detecting vulnerability within the grid.

One of the key limitations of the system is total dependency on SCADA data. Though any traditional system monitoring largely depends on SCADA data, in such cases human intelligence is used for further filtration of bad data in decision making. However, considering the automation involved for System Monitoring Tool, dependency on accuracy of SCADA data is very high. To have better accuracy necessary, cross referencing to check healthiness of data such as considering value of both the busses in station to ascertain voltage limit violation, considering power flow value at both ends as well as CB status and also change in power flow w.r.t. previous minute flow to ascertain line tripping's and overload scenario, considering line flows of flow gates during ATC / TTC violation conditions etc. has been included in the system. However, accuracy of the information flow and intelligence of the system largely depends on accuracy of SCADA data and healthiness of SCADA and Internet communication links.

Nevertheless, if suitably designed, the Grid Monitoring Tool as a bi-product also gives a check on healthiness of the SCADA data and necessary alarms can be configured to intimate SCADA maintenance group regarding non-availability / validity of real time SCADA data considering the result of aforesaid cross references.

VIII. FUTURE SCOPE

The scope of the application can be suitably enhanced by encompassing more parameters and logical analytics within the Grid Monitoring system. The application can in future be expanded to include SCADA snap shots (in picture format) to be sent as MMS along with the conventional text messages to provide better situational awareness to end user. For such purpose automated triggering of SCADA snap shots can be achieved through a separate function which will be called on if any emergency alert is generated by the Grid Monitoring system. Smart phone enabled Mobile applications can also be integrated as future scope. For this purpose, interoperable services can be ensured by using Service-Oriented Architecture (SOA). SOA services feature loose coupling, in contrast to the functions that a linker binds together to form an executable, to a dynamically linked library or to an assembly. SOA services also run in "safe" wrappers such as Java or .NET, and other programming languages that manage memory allocation, allow ad hoc and late binding, and provide some indeterminate data typing. The mobile apps to be developed can bind the alerts / triggers generated from the Grid Monitoring system depending on the violations along with parameters and provide real time grid awareness through geographical / network display.

IX. CONCLUSION

With increasing complexity in real-time grid operation it is extremely essential that more and more involvement of the market players, reliability coordinators, system study and planners etc. is ensured. Enhanced situational awareness of all the concerned can help to run the grid in safer and more secured manner and dependency on efficiency and intelligence of real time grid operators can be largely shared.

The Grid Monitoring Tool provides a seamless tool to enable all users have this situational awareness and ensures involvement of more & more experts during emergencies. This also enables to capture all near-miss scenarios which can turn out to be potentially dangerous.

One of the key advantages of this system lies in its simplicity in implementation and cost effectiveness. As all typical SCADA systems provide suitable tool to dump real-time data in any standard tables / DB systems such as MS Excel, MS Access etc. the process of monitoring, comparison and decision making of the system state can be achieved through simple scripts in any standard programming language such as VB, C++, JAVA script etc.

In general as on date typical web based SMS service providers charges 15 to 20p per SMS, considering the system parameters going out of normal / stable state to alert state typically 10 to 15 times a day and SMS is needed to be sent to 10 interested members in each time typical cost of this monitoring layer works out to be Rs.7500/- to Rs.11000/- only per year.

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