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CONSEIL INTERNATIONAL DES GRANDS RESEAUX ELECTRIQUES
INTERNATIONAL COUNCIL ON LARGE ELECTRIC SYSTEMS

STUDY COMMITTEE D2
INFORMATION SYSTEMS AND TELECOMMUNICATION

2013 Colloquium
November 13-15, 2013
Mysore – KARNATAKA - INDIA

ROLE OF ICT IN POWER SYSTEM. (D2-01_27)

WIDE-AREA MONITORING by PMU.

By

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(Country ISO code 2 character)

SUMMARY

In Power Systems, Security refers ability to survive imminent disturbances without any interruption. Ensuring Security requires use of advanced power system analysis tools capable of comprehensive security assessment. It models the system appropriately, compute security limits in a fast and accurate manner, and provide display to system operators.

Online dynamics security assessment can provide the first line of defence by scanning the system for problems and providing operators to take actions. With the development of leading edge technologies like **Wide-Area Monitoring by PMU's** is expected to become one of the dominant weapon for monitoring, Control and protection.

KEYWORDS

Our technological powers increase but the side effects and potential hazard related to security also escalates.

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INTRODUCTION

Recent 30th, 31st July 2012 blackout experiences are driving the industry to develop more automatic, adaptive control system to prevent such disasters. Analysis highlighted to have means and tools to avoid system power failure.Currently; a WAMS consists of advanced measurement technology, information tools, and operational infrastructure that enable the planning, operation and management of large and complex electric power systems. In its present form, it is used typically as a standalone infrastructure that complements the grid's conventional supervisory control and data acquisition (**SCADA**) system.

In this role, the WAMS is expressly designed to enhance the operator's real-time "situational awareness", which is necessary for safe and reliable grid operation in addition to supporting post-event analysis of significant system disturbances. In the future, developing WAMS technologies are expected to be become integrated into the real-time control system of the grid. Because of the current significance and potential future criticality of WAMS infrastructure, its security and reliability have become high priority issues.

As the major focus of this study, on WAMS using PMU.The data provided to a control center by a WAMS network is similar to SCADA data; message availability and integrity are the primary security objectives. As WAMS data are incorporated into real-time grid control applications, measures that ensure the message itself can be explicitly trusted become increasingly important.

The Challenges

Reliable electricity supply is the backbone of modern societies. The dependency of economic, Industry and public sectors on uninterrupted power supply is tremendously high. At the same time the risk of blackouts is increasing due to a change in power system development, which can be observed in almost any country of the world. This change is characterized by growing load demand, distributed generation, renewable energies, liberalization, smart grid technologies and new transmission equipment. Owing to these changes, power systems operate closer to stability limits. Simultaneously, the number of active elements and possible remedial actions in case of stability problems are increasing. As a matter of fact, this has already been recognized by most regulating agencies, and as a consequence of large blackouts an increase of situational awareness has been claimed. To correctly assess a power system's stability, the operator needs to know the stability margin and have assistance during the decision making process when it comes to finding the most sufficient solution in case of stability problems.

LEADING EDGE TECHNOLOGIES

Grid operations are complex in nature and are to be maintained under strict grid codes and operational efficiencies. When the limits of power system equipments are to be determined dynamically or systems are to be rescued from a near potential collapse, availability of real time data representing real time network conditions are important to the operator. SCADA systems are widely deployed in transmission and grid operation centers for monitoring of the network parameters. But these SCADA systems updates analog data typically in 5-10 seconds range and hence which will not be able to represent real time state of the network. Usually, to represent the dynamic state of system, the information is required at a scale of 20 msec to 1000 msec. Synchrophasor technology can help deliver a better real-time visualization required for a smarter and stable grid, with a wide deployment of phasor measurement units and using high-speed, reliable and secure communication systems. The real time situational awareness and decision support systems enhance power system stability and reliability. Typically, the stability boundaries are determined by voltage, frequency and angular separation between different interconnections. Secure operating region is the initial state of any power system operation and when the system tends to violate from its optimal operation limits, the system needs to be brought back with minimal co-ordinated actions. Wide Area Monitoring Solutions help monitor grid stability and provide a wide area situational awareness in real time by deploying Phasor Measurement Units, Phasor Data Concentrators and WAMS analysis and visualization system on standards based protocols and communication channels.

WIDE-AREA MONITORING by PMU.

What is PMU? A Phasor Management Unit A device –(microprocessor based unit) which reports the magnitude and phase angle of an analog and /or derived phasor with respect to the global time reference, as per the synchrophasor standards (IEEE 1344, IEEEC37.118).

Synchrophasors are vector measured values, that is, the magnitude and phase of the current and voltage are measured and transmitted. Applying a time stamp to the transmitted vector measured values allows a comparison of the measured values from different locations in the network.

Synchrophasor: A Phasor calculated from data samples using standard time signal as a reference for measurement,Synchrophasor measurement is being widely adopted and deployed on many power systems, as their benefits in power systems operations become accepted. A wide variety of devices now support synchrophasors, from stand-alone PMU's, to protection relays, meters, fault recorders and other substation devices.

Standardization of synchrophasor communications by IEEE C37.118 allow users to select best-of-breed equipment from various vendors, and integrate them into their applications. However, as the number of installed synchrophasor capable devices increase, utilities and integrators begin to face the problem of scalability in integrating large numbers of these devices.

Why is PMU important?

PMUs collect location, time, frequency, current, voltage and phase angle

- Large unexpected variability due to wind energy
- Can produce phase instability

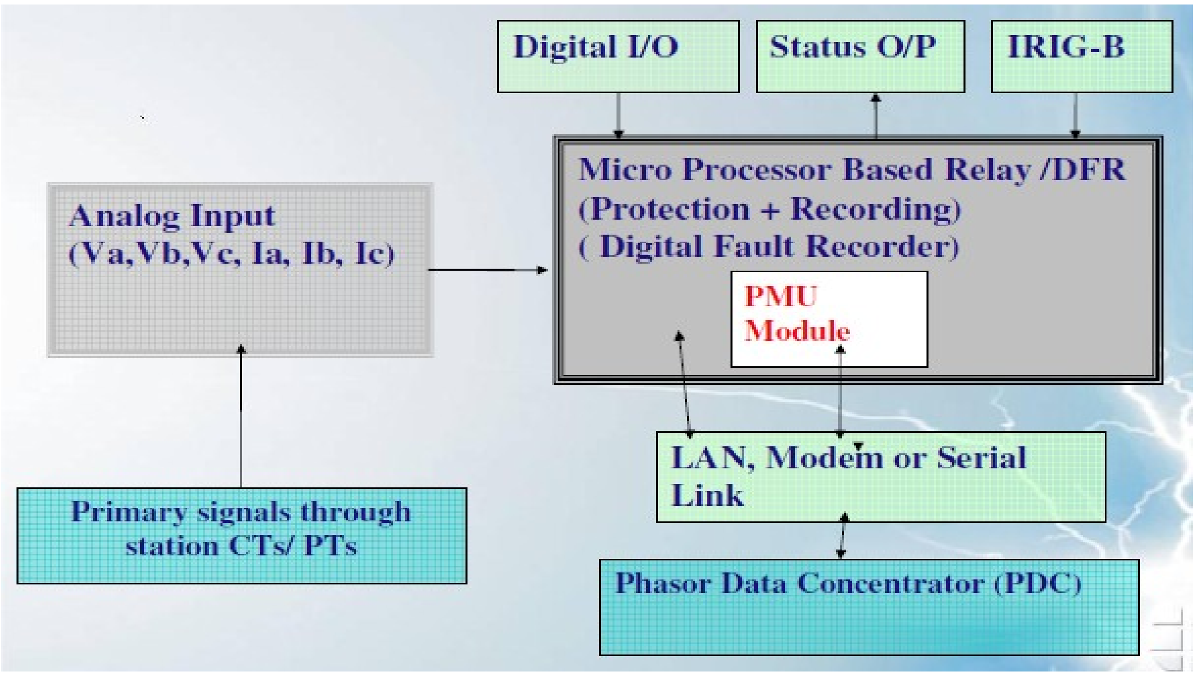
- Results in poor decision making [ex: scheduling]
- Which can lead to big problems [ex: voltage instability, islanding, cascading failures]
- Directly provides the phase angles [from State Estimation to State Measurement]

Basic differences from "conventional" measuring points at substation automation or in RTU

Measured Values from Sub-Station Automation Systems or a remote terminal Unit	**Synchrophasor from PMU**
Slower updating Cycle (e.g. once every 5 Sec)	Continuous updating (e.g.10 Values per sec)
Measured Values without time stamp	Each measured value with precise time Stamp
RMS values without Phase angle	Current and voltage are supplied as a vector value with amplitude and phase

With reference to above comparison it is very clear to have precise control over the system, updated information is required, Therefore PMU system needs to be incorporated that can give accurate and precise information.

PMU functionality with integration relay and DFR (Digital Fault Recorder)



Standards on PMU

PSRC working Group H7 :1994 : Synchro Phasor Standard Paper
1995 : IEEE 1344 Synchro Phasor Standard
2005 : IEEE C37.118 replaces IEEE 1344
2011 : IEEE C37.118 Split in to Two Standards
Revised PMU Standard IEEE Protocol C37.118

Wide Area Monitoring and Control with PMUs

WAMS system consists of Phasor Measurement Units (PMUs) placed at strategic locations of the grid. In comparison with conventional systems, PMU determine RMS values of Voltage, Current and angular difference between a global reference signal and incoming V & I inputs. PMU uses digital signal process and mathematical engines to derive quantities and continuous time synchronization methods for deriving accurate time stamps for data sets.

Features of WAMS

- Vector view or time chart view can be selected for all phasors
- Calculation and display of the power system status curve
- System monitoring, incl. communication links and PMU status
- Geographic overview (based on Google Earth)
- Basis for fast reporting after faults
- Flexible analysis with formula editor for calculations based on measured values
- Limit values that can be changed online

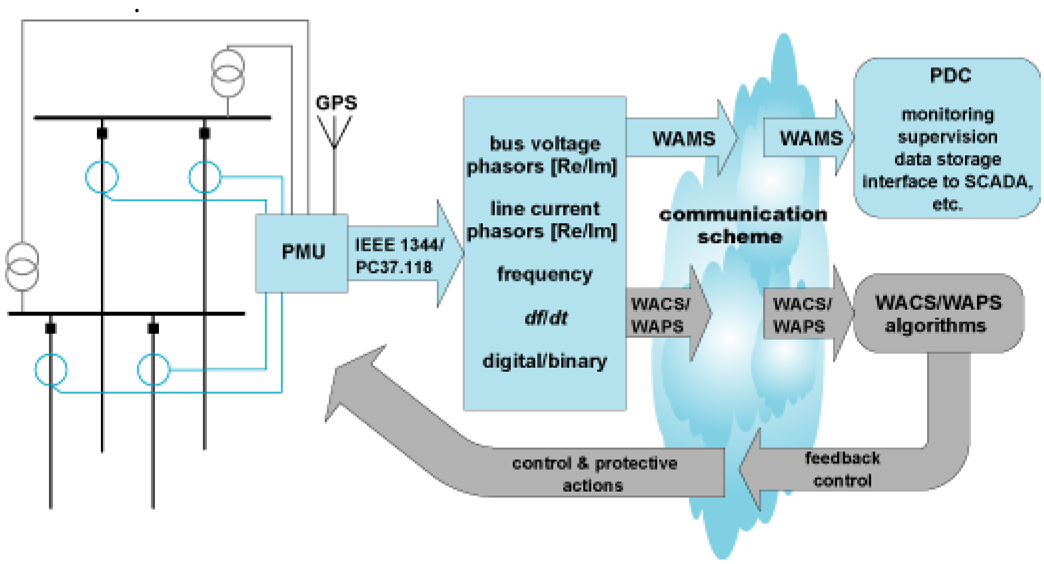
Time stamps are derived from a highly accurate clock which is synchronized to a global time reference satellite. PMUs receive time data, as well as accurate second pulse from GPS receivers. The collected data will be send to a phasor data concentrator over C-37.118 communication protocol and updates at rate defined by the user and requirement. Stability and accuracy of clocks are very important as the reference wave form is generated from the clocks, and a time error of 1µ sec can induct 0.018 Hz in 50Hz system.

Phasor data concentrator receives data from multiple PMUs placed at different locations of the power system network and aligns the data received in a common time scale and sends to upstream data concentrators (DCs) / applications for further analysis. The application can be a visualization tool, historian and analytics or protection functions. PDCs can be part of centralized or de-centralized WAMS architecture.

As the phasors represents dynamic characteristics of system, data shall be effectively displayed to the operator for better understandings of the system. Typical visualization system includes following displays. System frequency responses (Hz and df / dt)
Path dynamics-relative angular difference between major nodes Phasor plots-Voltage magnitudes and Phasor plots with respect to reference selected MW and MVAR transfer paths. The communication system plays an important role in WAMS. The PMUs send data at 50 seconds and the data need to be unpacked and time aligned with the packets received from other PMUs / PDCs. Dedicated F.O network, MPLS, VSAT are the among communication mediums for data transmission. When multiple communication medium is selected, the PDC shall have a delay time configured for the highest round trip delays in the network so that PDC will receive all the packets from all the PMUs and align time as required. A dedicated network

will be the right choice for WAMS, as there will be lesser hops and lesser intermediate devices like, routers and switches. Bandwidth should be selected based on PMU data packets (C-37 packet) as well as remote configuration utility packets (http, ftp).

The capability to model and simulate electricity grid behaviour over a range of time, frequency domains, and topological resolutions are one of features. It comprises fast dynamic tools for angle transient and voltage stability and modelling to simulate. The FTD techniques with quasi-dynamic simulations help to evaluate cascading and islanding during the system recovery.



The objective here is to keep intact electrical network with all generators connected to the grid. The infrastructure combines EMS software, PMU, fast processing and communication of information to the transmission level. All PMU information is captured at the substation level is used for local control, where actions are taken to adjust equipment settings, PMU quantities are further send to a PDC (Phasor Data Concentrator), from where the information is sent to a central place to EMS.

Power system normally oscillates at lower frequencies due to dynamic load generation deferrals as well as internal characteristics. Improperly damped oscillation in system can grow and which can go out of control. WAMS can act as an input to Oscillation Monitoring Systems (OMS) that is typically implemented as an online analysis tools to determine the oscillation in the system. The OMS has an event analysis engine based on algorithms like pony analysis for post-disturbance data and a damping monitor engine doing FDD analysis for ambient data. The OMS helps in the early detection of poorly damped oscillation and triggers warning signals based on the inputs.

Along with WAMS it is essential to have real-time data software for acquiring system, storing and displaying large amounts of operations and engineering information. It will collect data from Communicator deep within the enterprise and stores it in a highly compressed format, allowing time-series data to be stored online in its original resolution. It enables accurate and timely performance-based decisions that improve operating costs. Collector to store the parameters relevant for identifying the performance of individual equipments. Along with the process parameter it continuously records the status of equipment.

Applications of PMU:

Wide Area Protection

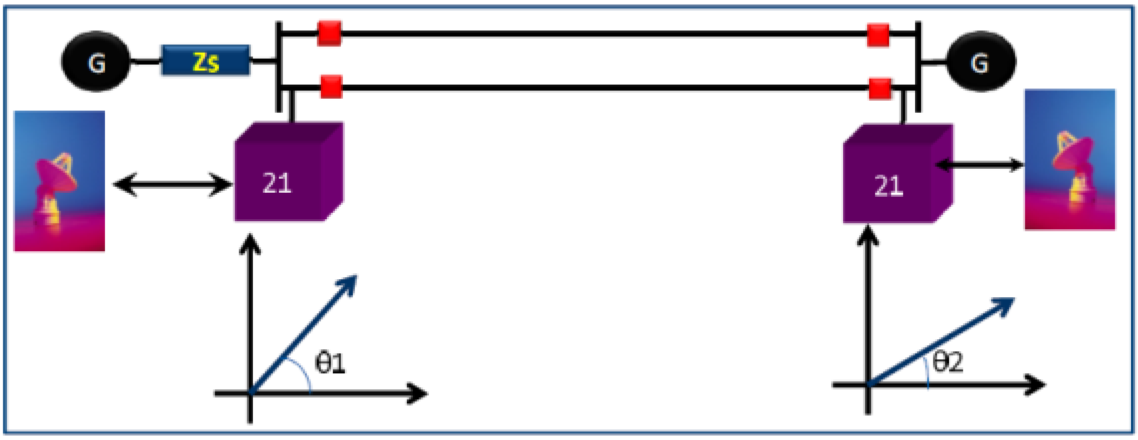
There exist always some disturbances in a power system but the time scale in which the dynamics of the disturbances may vary from milliseconds to minutes. Time also depends upon the nature of the disturbances. To take corrective actions on all such cases there is a need of protection which should consists of the following factors:

- Classification of the disturbance;
- Location of the disturbance;
- Identification and prediction of disturbance.

The knowledge of the complete state of the power system, represented by several network parameters, requires real- time state measurements as an input. Adaptive approach is preferred in such circumstances, possessing ability to adjust to changing conditions. Relays that participate in wide-area disturbance protection and control. The system measurements used in the relays must be related to the parameters that help observe the disturbance propagation. Such measurements must provide information about changing system conditions so that they will be useful in the management of the disturbance. PMU can explicitly fulfill this requirement of power system. Voltage magnitude, voltage phase angle, current magnitude, current phase angle, frequency and rate of change of frequency are provided by PMU. All given states are real time, time synchronized accurate and error free because these states are directly measured from instrument transformers. Therefore there are very rare chances of malfunctioning and system will remain stable. PMU situated at the both ends (sending and receiving ends) of the transmission lines and continuously give time synchronized system states to a remote location.

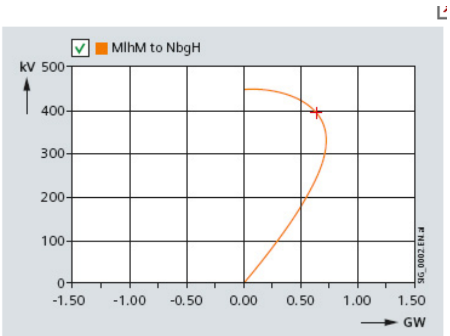
Wide Area Monitoring

Using real-time information from PMUs and automated controls to predict, identify, and respond to system problems; a smart grid can automatically avoid or diminish power outages, power quality problems and supply disruptions. A Phasor network consisting of PMUs spread through- out the power system, PDC collect the information from PMUs and GPS time stamping can provide a theoretical accuracy of synchronization better than 1 microsecond. “Clocks need to be accurate to ±500 nanoseconds to provide the one microsecond time standard needed by each device performing Synchrophasor measurement.” For 50 Hz systems, PMUs must deliver between 10 to 30 synchronous reports per second depending on the application. The PDC correlates the data, controls and monitors the PMUs.

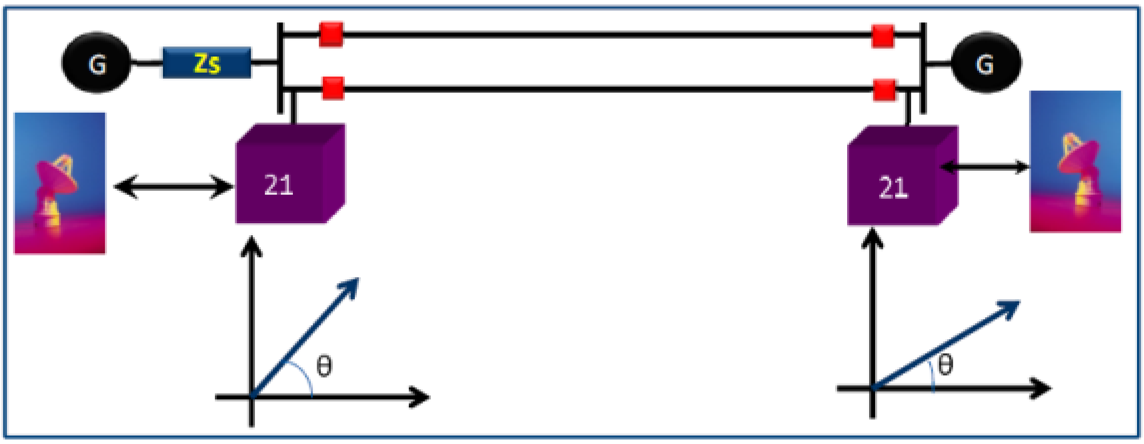


Calculate the angle difference due to disturbance
Apply equal area criteria
Make stability decision

Monitoring of power swings



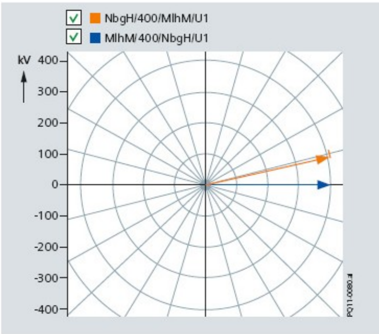
All measured values from PMUs can be displayed and monitored with easy-to-configure Phasor diagrams and time charts. Any power swings that occur are quickly and reliably detected. The zone being monitored can be flexibly adjusted to the current situation in terms of time, geography, and content.



Angle will vary due to disturbance
Algorithm determines if diverging or settling
Blocking or tripping decision
PMU provides Phasor in real time
Better decision can be made on load shedding and system stability
Real time Phasor Value helps to fine tune state estimated load.

Evaluation of the damping of power swings

Using the function "Power Swing Recognition" (available as from Version V2.1), an incipient power swing is detected and the appropriate damping determined. Detection of a power swing and, if applicable, its insufficient or non-existent damping is signaled (alarm list).



With help of PMU, WAMS can display a clear and up-to-date image of the current power flows in the system with just a few measured values from widely distributed Phasor measurement units (PMU). This requires no knowledge of the network topology. The power flows are shown by means of phase angle differences.

Phase angle Monitoring

Through PMU one can monitor real time Phase angle of different nodes accurately because it is time synchronized and accurate PAM (Phase Angle Measurement) is too much important for a power system. PAM enables access in real time to the accurate phase angle difference between any pair of buses. PAM allows prediction of potential problems both locally and regionally. Monitoring the rate of change angle separation between two buses to determine stress on the system. Another critical application of PAM is during restoration. The phase angle value across an opened tie line or an opened circuit breaker would guide an operator in circuit breaker closing. Closing would take place only if the phase angle was below a preset threshold. The information obtained from PMUs can be also included in the CB interlocking logic.

Monitoring of the load on transmission corridors

The voltage-stability curve is especially suitable for displaying the instantaneous load on a transmission corridor. The currently measured operating point is shown on the work curve of the line (voltage as a function of the transmitted power). In this way, the remaining reserve can be shown at any time. This requires PMUs at both ends of the line.

Dynamic Islanding:

If all lines of defence are exhausted there is last possibility, to separate the network into small f-V controllable islands. The control actions should be highly automated and they should be provided with enough intelligence to figure out the right alternatives.

Island state detection

One of the functions automatically indicates if parts of the network become detached from the rest of the network. For this purpose, frequency differences and rates of frequency changes can be automatically monitored. If islands are detected, warnings and event messages are output.

Retrospective event analysis

WAMS is ideal for analyzing critical events in the network. After switchover to offline mode, the entire archive can be systematically analyzed and the events played back as often as necessary. This makes dynamic events transparent, and reports can be quickly and precisely compiled. Simply copy the informative diagrams from SIGUARD PDP into your reports.

Alarming on limit value violation with an alarm list and color change in the geographic network overview map this allows you to locate the position and cause of the disturbance quickly. This function is also available for analyzing the archive.

Display of the power system status as a characteristic value for the stability of the power system Due to the constant availability of the power system status curve in the upper part of the screen, the operator is constantly informed about trends in system dynamics and any remaining reserves. This curve shows a weighted average of the distances of all measured values, to their limit values.

Utilization of WAMS facilities: Detection, recording, analysis, and reporting of System behavior

Transient Stability

- Real time information helpful in observing stability of the system (e.g. PV curve)
- Small Signal analysis (e.g. modal analysis)
- Real time stability control is possible – especially with synchronized sampling on PMUs

System Modeling

- Transmission line modeling
- Driving point impedance is helpful to understand frequency response of the system
- Useful for training intelligent systems- such as – Neural Network,
- Fuzzy logic – training samples are available with real system data

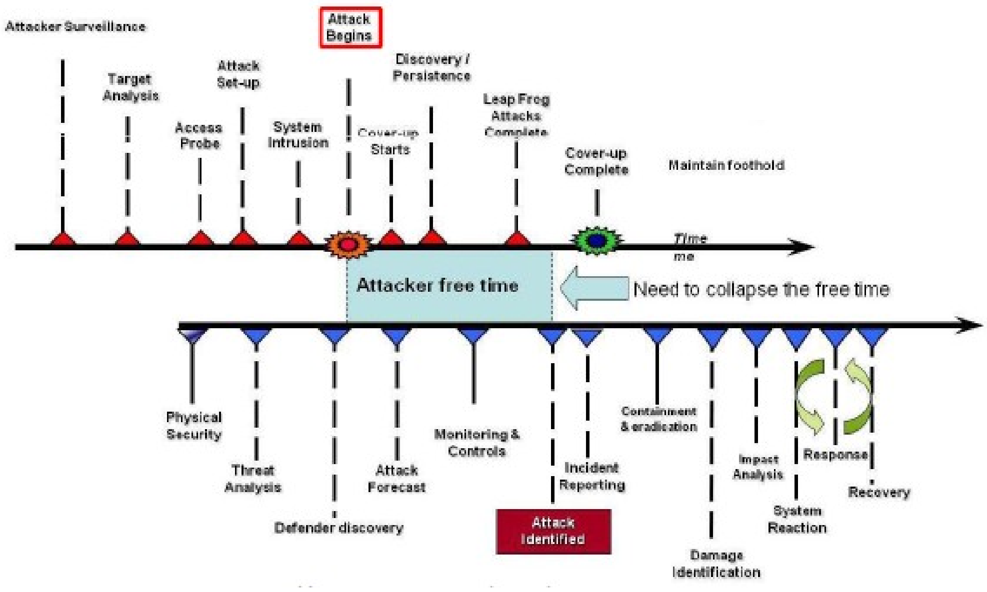
Security System for PMU

Cyber-security is one of the main obstacles to widespread deployment of PMUs
Integrity attacks are most critical which may cause

- Can initiate inappropriate generator scheduling.
- Can result in voltage collapse, and subsequent cascading failures.

To ensure Safe and secure operation of system it is essential to do consistent checking between cyber network [PMU data received] and physical network [load flow equations] using static state estimation tool. Further Enhancement in System for removing loopholes in potential attack points needs to be addressed.

Potential Attack points



Conclusion:

The paper provides a general idea leading edge technology using WAMS by PMU. It can help to monitor and give precise information to operator to take correct and appropriate decision, Secondly the protection system and retrospective analysis of fault can be done with help of PMU, it also briefly explains some applications that is, monitoring swing, load on transmission corridors, phase angle and disturbance monitoring as well as protection and control related applications. Since future power networks will become more difficult to guess during both steady-state and transient conditions, WAMS using PMU systems will become an essential addition to every control room. Security and

Acknowledgement:

I am thankful to Shri Vijay L. Sonavane. Member (Technical), Maharashtra Electricity Regulatory Commission for contentions support and guidance.

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