Applications of Protection Relays in the 21st Century in Smart Grid Challenges

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Abstract - *Thriving fundamentals of Smart gird that come up with ever-assimilating new technological innovations and concepts specially with protection relaying are attracting huge attention of power grid community. This expanding role with the help of huge data management, latest communication equipment, power control techniques and notably corresponding faster and adaptive settings response of intelligent Electronic devices' (IEDs) to the network changes is gaining great momentum. Importantly, this paper shed a light over major aspects and components of smart grid in relation to increasing role of protection relays and associated technologies, especially how protection relays readying themselves to take up the role of control as considered earlier " not in protection domain". Protection relays respond to re-configuration of network and additionally resort to self-healing and artificial intelligence or machine learning based decisions in determination of changes in relay settings. Further to this, specially addressing the surfacing challenges due to Renewable generation (REG) cyber-attacks in protection relays specifically and smart grid in general.*

Key Words: **Smart Grid, Relays, PMUs, Adaptive Settings, Asset Management, Cyber security.**

1. INTRODUCTION

Concept of Smart Grid is primarily an approach and implementation of state of the art technological advancement into Electrical power system. In the same vein, advancement in protection relays with cutting-edge communication components have revolutionized the performance of power grids. As the voluminous research over different segments and elements of power system has pushed with staggering responsibility for electrical power community to crystalize and embed all latest innovation in the skeleton of power grid and proceed with increasing reliability, security along with meeting all latest standards, requirements and norms. These virtues have proved strong foothold thanks to the benefits garnered through the power grid components ranging from renewable generation to Distributed generation, from involvement of Machine learning techniques to adoptability of EV system connectivity with the power grid, from adaptable protection relays settings to increasing roles of PMUs and most importantly meeting the subsequent increasing challenges of cyber security, from All those components are designed and addressed in such a way to obtain maximum possible optimal requirement with efficiency and sustainability for overall electrical power system. Actually that comes under the umbrella term as Smart grid.

Smart grid system consists of digitally based sensing , data management, communications, computing, and control technologies and field devices that function to coordinate multiple electric grid processes .The application of Information Technology allows utilities to handle greater quantities of data that facilitates for more effective and dynamic grid operations .

Electrical power industry is not out of race in challenges/objectives as horizontal growth such as meeting demands of increasing population coupled with incremental commercialization and industrialization leading to load increments that cause complex networks at one hand and embracing the vertical progress with the help of automation technology and now artificial intelligence on the other hand. Alongside of micro-level development in each segment of power components dating back to century long continuous progress has bestowed power industry with great deal of huge benefits. However, this development varies in different domains, for example different electrical power entities utilize benefits individualistically which has caused some gaps and resultantly leading compromised uniformity or converging design platforms. Almost last two decades or more, IEC61850 standard has steered a robust hold on substation control and protection aspects over today's technologies and processes. On top of that, power grid technology has embraced smart grid concepts which takes into account all best and filtered aspects in one go. Management of heavy flow of data between the different digital devices or channels and protection relaying with embedded time stamping components such as PMUs and network reconfiguration aligned with adaptable protection settings or a relay that maintains lifecycle data of associated components and give rise to efficient asset management concept, as appearing major convincing feature in smart grid. Accordingly, this paper assesses the smart grid role in domain of protection relay technology covering the contributory aspects as below:

2. Role of Adaptive protection settings in smart grid

Adaptive relay settings concept is motivated by network changes due to faults or other network switching. Our latest digital relays are expanding and upgrading their functionalities and performance with passage of time. However, it has been felt the missing link to bring these advanced relays to its full functionalities. For example, many utilities are still static in their approach for different settings in one relay. As smart gird where it has taken many innovative and efficient technologies in its design and implementation, it has progressed efficiently for changing relay response to different conditions. It encompasses smart approach where immediate and automatic response is increasingly becoming paramount importance with network changes and consequently major efforts to cater the changing needs that have been resolved by the adaptive settings.

Major threat to power system is due to black-outs. There is major contribution of protection relays' non-operation or nuisance operation when system is stressed out and cascaded events lead to black-outs. The underlying reasons may start with planned outage coincided with mal-operation of relays or along with this unwanted component mal-operation comes up inadvertently, then cascaded events are bound to transpire. Preference of security vs dependability or vice versa is long debatable point for power system engineers. If we assume power system is in stressed condition, preference for loss of dependability somehow lags behind slightly to loss of security. Hence, this is the point where power system engineers minimize this uncertain conditions or grey areas and its solution is found in adaptable response to such changes in power system by dint of automatic changes in the relay settings. Thus new algorithm is based on new concepts that provides means to security-dependability bias of groups or different array of protection settings and logics that is independent and make the corresponding decisions adaptively through changes in the relays settings. There are numerous related examples for adaptability of protection relay settings some of them are discussed as below.

Distance relay is a major protection used for protection of transmission lines in power system. Back-up protection zones i.e. zone-3 that provides effective time delayed protections for remote lines connected to next substation. Historically, undesired tripping of distance relays zone-3 has caused black-outs. Mal-operation of zone-3 is mainly caused by transmission lines in stressed conditions. Though protection relays have incorporated the feature to counter the challenges related to load-encroachment, power swings and voltage instability. However, these features sometimes still fall short of requirement and results in mal-operations. Thus, single mal-operation of a relay develops further stressed conditions to adjacent lines due to similar relay algorithm response and releases the trip to the circuit breakers of the lines. This problem can be well tackled if we keep two or more different settings in the relays satisfying the system conditions. For example, if the relay in normal conditions has one range of setting parameters or associated logics; subsequently, it switches to other setting parameters or group if the information of system stressed conditions are recognized by relay itself or signaled extraneously. The latter example of adaptability is fulfilled with the help wide-area networks where information is streamed when the stressed conditions set threshold is reached.

There is much growth in non-conventional generations, simultaneously, distributed generations (DGs) are seen making a way into the power distribution network. Inherent decreased short circuit of Distributed Generations (DGs) is demanding task for conventional relaying settings that are calculated on maximum and minimum short circuits being far greater than what is in DGs oriented short circuit current. This demerit is addressed with the help of adaptive settings in smart grid concept. [1]

In distributed generations (DGs), bi-directional overcurrent relays do not satisfy all protection of short-circuit scenarios. Increasing penetration of DGs in power system specially in distribution system of smart grid make power engineers to apply the adaptable protection schemes ready to respond the all major changes in the network affecting the short circuit so the overcurrent operation of the relays. Hence, short circuit can be viewed as in single source supply of electricity in DGs. This scenario is also similar for energy storage at the grid point that discharge or export power back to the grid. DGs' DC/AC converters phenomenon with lesser short circuit current necessitates feature protection settings to be lower to meet the required overcurrent protection operation. This cannot be achieved in single settings which normally is based on traditional overcurrent. However, this necessitates to provide a means to automatically adapt to network reconfiguration. [2]

IEDs along with extended role of IEC 61850-7-420 with new data models facilitates to play a role beyond substation bound automation and communication. It covers dynamics of distributed energy resources (DERs) within its framework. IEDs here in combination provides robust and multi roles of protection, automation and communications. Taking the overall status of distribution network with well-defined object-oriented information model of IEC standards makes possible to be interoperable and transfer the information of any changes in the settings based on networks or corresponding equipment status changes. [2]

Power protection engineers take all scenarios where optimal settings for relays should protect the object considering flexible conditions of power system but non-adaptability of protection settings sometimes bring in disadvantages. This rigid settings at certain scenarios do not always meet the protections settings. Accordingly, adaptable protection settings achieved in broader sense through modelling of power system at different conditions, these conditions can be as under:

- Power Generation in full Capacity.
- Transmission lines loss as an individual and or cascaded manner.
- Power transformer out form the specified network.
- Main grid loss.
- Generator loss from range of one to many.

These above scenarios or push protection engineers to go for more precise settings in line with different network conditions. Hence different protection relay groups house distinct settings in line with broader network or generation/load conditions. These settings group changes are be triggered by relay internal logics through changing system conditions or binary inputs of the relays. [3]

3. Self-healing process protection relays

Power system is characterized by different transients, sub-transient and dynamic changes. In smart grid concept, self-healing of power system has proved one of major enablers to respond to its changes. The scope ranges from network reconfiguration, necessary adjustments, load shedding and voltage control without human interference. [4]. Further, phasor related information with reduced delays at different points of power system is proving great advantageous in smart grid concept.

To achieve this objective power system is furnished with modern sensors, wide area control, advanced software and communication system that visualizes real-time data received through different channels. Hence, during faults, abnormality or overloading, the system takes own decision to minimize the affected are of distribution power. [4]

There are numerous equipment in a substation or designated area or section of power system needs to be monitored from its basic electrical quantities to the status and healthiness of the equipment. Based on this data, desired decisions are selected or programmed through IEDs or subsidiary equipment to reach the objective of self-healing. Information received at different points of gird for implementing the process based on Self-healing current, voltage, health of equipment, device mal-function alarm, fault location or fault direction, pressure, breaker, switches status etc. are some examples. [3]

4. PMU in smart grid

The synchrophasors are used now as internal function of protection relays and DFR (Digital fault recorder) due to acceptance of increasing scope. As it incredibly minimizes the data communication time delays of phasor information of voltages and current at different points of power system as facilitating the data more near to real time so the minimizing the blackouts. [3]
Synchrophasor concept along with control and monitoring of power system has got importance in the field of protection relays. PMU (Phasor measurement unit) the unit or device which performs phasor measurement of the electrical power signals and send the information to PDC (Phasor data concentrator) which further sent to control room system for monitoring of respective protection relays helps to execute protective function in greatly decreased time. Data reporting rates for these parameters is typically 30 to 60 records per second, and may be higher. In contrast, current supervisory control and data acquisition (SCADA) systems typically report data every four to six seconds – over a hundred times slower than PMUs. [5]
The PMU is the major components of the wide-area measurement system (WAMS), synchronized information of phasors is utilized for monitoring, measurement and protection purpose. Global Positioning System (GPS) has accuracy less than 1 micro second or phase angle error is translated at less than 0.021 degree. Along with phasor information of current, voltage and frequency. Hence, it facilitates to provide the circuit breaker and other switches status information in almost real time. Further, this provides quick snapshot of overall power system information in the most accurate possibility.
The role of PMUs in control and measurement aspects has been much realized, while in protection perspective, information related to PMUs may not compete the sub-cycle, cycle or slightly higher trip time of Line differential or distance relays.
However, backup protections like time-delayed protection as zone-3 of distance relay neutralizes the associated disadvantages of nuisance tripping of zone-3 on load encroachment and corresponding tripping on healthy lines.
Other protection and control related functions performed by PMUs are as below:

- Steady-state stability of Generators through Loss of Field relays.
- Transient Stability through Out-of Step (OOS) relays.
- Stability check/control through Oscillation check
- Load shedding through intelligent methodology.
- Voltage stability [7]

This may be taken as a real new concept on the controlling the power system and,
especially the power flow. A more specific example is the detection of power system oscillations with the help of synchrophasor measurements and the use of FACTs for the related damping control. [4]
Distance relays' zone-3 sometimes is diagnosed with the mal-operation due to load encroachment that caused some blackouts, one of most undesired situation in power system is addressed through data of PMUs. One of incident in July 30, 2012 in India zone-3 of distance relays tripped due to load encroachment and corresponding tripping of distance on fast power swing left the power grid in black-out.
Real time monitoring of differential current of back-up lines through Relay supervisory scheme (RCS) facilitates the intelligent decision making for blocking the relay for trips which is determined as nuisance behavior based on PMU received data, resultantly avoiding the zone-3 tripping. This scheme involves subsystem which covers set of zone-3 relays of the designated and targeted portion of the transmission lines. This closed loop communication subsystem of RCS provides decision in 180ms, which covers the minimum time for zone-3 back-up protections, as zone-3 timing is much higher than 180ms. With the help subsystem, PMUs fast data for zone-3 of distance relays discard the un-faulted loops. Hence, provides robust system for non-tripping decision for zone-3 nuisance tripping.
[6]
Hence making it possible to take the snap of overall power system and paved the way for providing the solution.
These solution covers as transient stability improvement, reduction in outages, real time power

system measurements and retrieval of real time data used for multiple other protection and control functions. However, some challenges are still in place as most predominantly, communication losses, but a lot of research is conducted for resolution of issues associated with utilization of PMUs permanently and everywhere. [3]

5. Asset Management through protection relays in smart grid

Fundamental structural concept of smart grid is reinforced by the power system's status and behavioral information received through different channels of the power grid. When a protection relay is assigned as a source for collecting the data, then this is used as the best platform for taking the data for real time value of asset based on continuous monitoring in the Smart grid concept. This paves the way for real-time analytic-based information exploited to excel the smart grid objective in future. Processing and then prioritizing the data after embedded approached based on multiple analytics can provide marvelous grid resiliency. Hence system performance can be increased by real-time tracking of equipment health and further decision motivated by analytical tools. Further, high resolution cycle-by-cycle real time information obtained with the help of PMU as a part of protection relays will provide increased effective visibility of power system as a whole.[8]

Today's electrical power grid grown to the point as it embraces all the complexity and modern sophisticated equipment into its domain. Hence, relay's role in smart grid area has gone beyond traditional protections functions to the monitoring, diagnosis and condition monitoring of the equipment with retaining the pre and post fault information through current and voltage actuating quantities with the help of CT and VT secondary connected to the relays. Hence, Protection relays with its increased capabilities in hardware and software platforms has provided to perform additional duty of asset management of equipment directly associated with relays. [9]

As introduction of advanced devices and processes in smart grid, efficient and modernized ways must be in place to cater the monitoring demand of assets in the system and duly broadcasting the status of devices to the responsible engineers for asset management. This reliability and effective availability of working devices is increased with the help of regular collection of data, incorporating the asset management processes like asset management analytics, make different groups based data and their rationalization and most importantly developing the centralized asset health care processes. If we see the traditional asset management process, it is more based on principle to reduce the assets with high risks, but it lags to provide emergent requirements of power quality and reliability. Accordingly, new innovative methodologies are adopted in smart grid perspective with integrated asset management solutions by monitoring of protection and control devices to gather.

Revolution in electronic devices at one hand reduced the size of conventional electronic devices in general and electromechanical components in general. Traditional electronic devices came up with complex protections schemes. Hence, sometimes difficult to track all components lifecycle and other accurately time-bound maintence. However, today's advancement in protection relays facilitate to minimize the complex protection schemes and multiply the benefits with the help of power quality, metering, logics and control-centric applications of the relays made it possible. Proven efficient communication systems in substation set-up with advanced cyber-security with the help of IEC61850 standards along with the ability of advanced signal processing provide great deal of robust platform where historical data is collected and exploited to deduct the asset management or life-cycle management decisions of the equipment in communication with relays or otherwise. Further asset management capabilities are enhanced thanks to compactness of relays that has eased the testing, configuration and simulation [9]

When it comes to management of motor life-cycle, relays have excelled in their scope to the effective care and monitoring throughout the lifecycle. Protection relay takes the magnitude of thermal stress of stator which is considered the major factor of degradation in insulation. The protection relays monitoring through different sensors or subsidiary components help to take account of cooling system failures, winding hot-spot heating, single phasing condition, Total harmonic distortion, extreme starting conditions and unbalance or overload of the current. These factors and more like that, play decisive role for condition determination of gradual degradation of motor life-cycle. As we are aware that, inter-turn faults of stator winding are motivated by insulation deteriorations.

Synchrophasors embedded in protection relays are set to start measurement of almost accurate loadability of lines by extracting the information related to temperature of the lines by utilizing the data received from PMUs and then transferring to Phasor data concentrator (PDC). This kind of condition monitoring gives early particular systems signs for operators responsible to take corresponding action. Thermal limits of transmission lines are impacted by environment conditions such as wind solar radiation, wind speed and current passing through the conductor. Accordingly, loadability of the line is almost accurately provided. Hence operators are furnished with up-to-date information and take corresponding best possible decisions. This is termed as dynamic Lin Ratings (DLR) based on synchrophasors. [3].

Transformer is a major component of power system. As we have access to minute monitoring and subsequent analysis of transformer conditions. Monitoring or asset management through modern numerical protections relays is enhanced with integration of numerous standard protocols like Modbus, IEC60870-5-103, DNP 3.0 AND IEC61850 with communication option of RS485, FOs (Fiber optic) and Ethernets, that makes relays efficient enough to perform multiple tasks.

In such a way, transformers monitoring is carried out and same is used as major asset management tools.

6. AI/ML role in relays benefiting the smart grid objectives:

Smart grid has amassed all cutting-edge technological features to make power system more efficient, reliable and secure. Numerical protection relays along with all modern communication and control companions introduce multiple benefits and with new artificial intelligence (AI) and machine learning (ML) concepts. However, there is much volume and area of research for AI/ML to go through the implementation process at full-scale in power system. ML related concepts discussed here are not necessarily part of power system, yet these are proven and becoming a part of power system or in smart grid concept.

Machine Learning techniques perform the job, how computer processors with raw or refined data can be trained or learn to identify complex patterns and make intelligent decision based on those patterns. This ML learning is broadly categorized into two ways: One is supervised learning and other is unsupervised learning. [11]. Hence, with the help of these methodologies, complex problems with huge data dimensionality is reduced and pertinent information and data is received that enables to make right decisions.

Major challenge for power system engineer while adopting the protection designs is to opt for the best trade-off between reliability and security. There is always a boundary areas where one approach is compromised somehow to other for great benefits considered for power system. [10]. Hence we have to meet this challenge by adding the ML concepts in order to minimize the overlapping areas between security and dependability of relay settings and logics.

Different ML tools are used to obtain the desired results. As ML has self-learning characteristics, data received from the power system through electrical quantities and further this processed data along with different related equipment status (i.e. circuit breakers, isolators etc.) with additional through inputs provide wide range of information to learn and decide the emerging scenarios in power system (Self). New techniques through ML are embedded in the relays and are experimented to get the best possible results with minimum errors, these are: artificial neural network (ANN), decision tree, Fuzzy logic (FZL) etc. [10].

However, the question arises, what level of reliability and certainty can be achieved through these techniques where black-outs can be avoided. Though, there are convincing evidences that performance of the relays is much improved through ML techniques with the help of experiments, but complete reliance over the assumption to eliminate the total blackouts is still too early to be ratified by electrical power engineer's community. [10].

Hidden failures is one of causes of blackouts, other than considered factors such as human error, natural disasters, mechanical failures or so. Thus cascaded events due to hidden failures is addressed through ML techniques. As the power system contains numerous devices or equipment, the hidden failure remain dormant until another event expose the defect in equipment or process [10]. While SVM (Support vector machine) technique embedded into the protection relays is considered advantageous as compared to ANN in global solutions. SVM-based solution retrieve information through electrical actuating quantities and by analyzing the characteristic Hence, relay makes decision based on SVM information, either it has to trip to remove faulty area or/and not as causing the overloading or bring out hidden failures to the rest of system. Subsequently, other relays update the protection settings based on new topology after the tripping and simultaneously, this information is conveyed to control centers for further actions to avoid the situations that can lead to blackouts. [10].

Other example of ML technique is in the transmission lines, where the transmission lines undergo SSR (Sub synchronous resonance) problems normally. Hence, swing characteristic of SSR trigger Out of step blocking (OSB) feature of distance relays. Since, voltage and current are increased in these scenarios, Ferro-resonance is accompanied normally with these conditions. [12]. In order to tackle this situation neural network (NN) is chosen and trained to tackle this situation. During commissioning process, the relay is passed through the training procedure; subsequently, patterns developed are transferred to the algorithm of the relay. Henceforth, the relay is made capable to segregate ferroresonance waveform from other waveforms. [12]

Accordingly, wavelet and neural network differentiate ferroresonance phenomenon from other transient nature characteristics, such as transformer energizing, load and capacitance switching etc. [12].

7. Role of Distributed Generation:

The power system is growing its volume with respect to increasing population at one hand and standard of life on the other hand. New solutions has made its ways by introducing distributed generations (DGs) to meet the loads, it may be in individual capacity and/or to be connected to a grid at the time of need or regularly. DGs may consist of micro turbo-generators to renewables near the concentrated demand areas. However, Protection system of distribution faces some challenges in conventional power system. As with adoption of DGs, those distribution systems having radial system face OC/EF mis-coordination due to power flowing in bi-directional nature[13].

Overcurrent (OC) protection is the most common protection relay used in distribution system. Distribution system with fixed topology or network having rare changes can accommodate one fixed over current settings. However, DGs contribute for different scenarios where fixed OC settings will fall short to meet the required protection demands. Accordingly OC with different settings can meet the varying requirement of DGs. [13].

Incorporation of DGs in distribution system facilitate to bring in some advantages like enhancement in electrical characteristics that consists of voltage sag, power losses and stability. However, it begets some demerits specially related to protection relays such as flow of current in two directions and modification in nominal current of the line. Protections challenges are not limited to this, as DG underlies blinding protection, nuisance relay operation or tripping, mal-functioning of re-closers and unsynchronized reclosing are some examples associated with protection in DGs. [13].

The protection relays challenges in smart grid concept are met through innovation in protection relay settings and processes. One of solution is to adopt different settings or group of settings where different network configuration related to microgrid or DGs to the main network connections. Keeping different scenarios of distribution network, where microgrid is in islanding mode, or microgrid is in operation without generation or microgrid is in operational and connected to main distribution system. Further, within DGs internal network configuration, for example, different feeders may be ON/OFF causing different fault current and directions. These protection relay settings is prepared considering all scenarios and network configuration impacting loading and short circuits. Through this adaptive settings concept emerges and implemented in DGs in smart grid concept [13].

8. Agent-based protection system in smart grid:

A software agent is a computer program where decisions are made based on events in its surroundings. While relay agent can be elaborated as an IED with embedded software agent that communicates and cooperates to provide changing settings in line with the system requirement, that settings to be primary and/or back-up protection for smart grid. Multi-agent system uses the multi-cast protocol that beefs up the information to more than one destinations in IEDs with multicast system. These are set in the groups in order to ease the traffic on the network. [14].

This is intelligent system that implements adaptive protection or self-healing in power system, is based on primary and back-up protection zones. Power system communication with protections system with the relay agents. In order to obtain high selectivity in protection system, this primary and back-up relaying is extended in wide area of the power grid. [14].

This agent system is developed with number of experiments, where relay agents are passed through cascaded outage of communication and power system to test the viability and efficacy agent system concept. Primary and back-up protection are compared with optimized directional OC relay of interconnected grid. [14].

Intelligence system coupled with autonomous decision making is central core of the agent-system. Multi-agent system (MAS) consists of multiple agents that are connected in such a way to take collaborative actions when protection or control related problems are out of capability for single agent system. [15].

9. Benefits and challenges of growing Renewables in Smart grid:

Deteriorating environmental aspects due to power generation thorough fossil fuels have put strong pressure on governments and power generation communities to take decision to shift from conventional power generation to renewables. As electricity generation has huge proportion to total pollution in the environment. Accordingly, renewables are considered best alternatives and world's electrical generation as slowing shifting to this environmental-friendly technologies. Natural push due to fast urbanization and advancement in living style of people actually converges to smart city concept where broad use of Information and communication technologies (ICT) and usage of electricity has increased. Thus, complexity of power network in smart grid area has increased the responsibility of protection engineers to provide best design and settings solutions to meet this challenge. The frequency, disturbances in voltage and power outages and gap in power in demand and supply is the technical and economic motivation to the renewables. This has changes the traditional fixed rules for OC or EF (Earth fault) relays coordination concept as settings provided through consideration of single power source. However, due to DGs, different approaches are applied to meet the requirements. And the voltage operated OC relays are have also become part of new protection schemes.

As we are aware, many renewable sources are based on DC voltage, it brings about varying frequency and voltage, and inverters/converters units are part of these overall schemes. Resultantly, it brings in some power quality issues in the respective distribution system. Further, electrical power storage in distribution network comes up with new challenges of power flow and similarly protection burden over new avenues to be explored. [16]

9.1 Impact of Renewables and Energy storage in Distribution networks:

The Technological development of renewable energy generation units and related subsidies, as well as the changing structure of electricity market have stimulated an increase use of renewable energy sources but it comes with problems or drawbacks, Renewable energy sources will have an impact on the whole utility value chain.

Smart grids enable the integration of small distributed energy resources in the urban network, increase the customer awareness, provide real time optimization, and energy flows at the urban level enables interdependence and facilitating the linking of electricity network with other infrastructures.

The installation of renewable energy source in distribution networks has number of technical difficulties, the technical implications are being investigated and can be divided into four groups

- Load flows
- Voltage control
- Fault levels
- Network security

The above problems can lead to difficulties or barriers in operation and planning of distribution networks , with increased distributed generation penetration level in future .in this regard ,storage technologies will play a key role for electricity distribution network. Storage has the potential of increasing deployment with an increasing cost difference between peak and Valley hours. [16]

10. Applications of cyber security in protection relays

Interconnectivity through different effective communication channels or systems is a major base of modern power system. The more the sophistication is involved in automation and communication systems, the higher the risks and challenges appear. Historically, we have seen cyber-attacks in electrical power grids that has shown new challenges to power grid community. Moreover, smart grid is combination of more interconnectivity and decisions are based on communication information through different electronic devices or sensors. And Smart grid includes the concept of individual consumers' energy sharing on different commercial aspects. Thus, communication profile has even advanced and subsequently requires new approaches with counter technology to block these malicious intrusions. As the new standards and new series of actions are adopted by different power grids or utilities in relays to identify and safeguard the system from all these intrusions.

Cyber security is implemented in protection relays as one of potential source of threat through advancing security logging, user authentication and strengthening proper functionalities for most secure communication. However, implementation process to be done through applicable standards. Thus, cyber security supports users on role-based access, supervised protocols, services, communication ports, intelligent load monitoring and respective configuration for the software that are based on vital protocols and services. The cyber security is applicable for entire infrastructure of smart grid. These require robust security from all unwanted interferences and equally ensure effective functionality for all the time. The range of cyber security covers all today's possible threats, these may be due to espionage operations, criminal factors, natural disasters, equipment failures or vulnerabilities associated with errors of users. Therefore, huge research is done and underway to make the protection relays in smart grid more safe, secure and reliable from all kinds of these threats.

11. CONCLUSIONS

The new protection relays and protection schemes in smart grid have given great deal of improved selectivity, dependability and efficiency. Smart grid with protection relays, with the set of other efficient communication platforms and digital devices are proving to be most advantageous and equally, many innovative concepts through artificial intelligence are under full experimentation and in implementation stages is actually precursor for promising future and expected to reach an improved response to many transients or sub-transient problems associated with power system. It solidifies the numerous equipment's effective asset monitoring and management in smart grid and specially a timely preventive and corrective actions. Additionally, optimal solutions from conductor loading to complex distance zones operation are major benefits to be obtained. Finally, Smart grid with advanced protection relays is expected to be glittering future and advancement the smart grid or power system of 21st century.

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