USE OF SYSTEM INTEGRITY PROTECTION SCHEMES TO IMPROVE SUPPLY CONTINUITY

John William Wright
ALSTOM Grid – UK
john.w.wright@alstom.com

ABSTRACT

For many Transmission and Distribution Network Operators the demand for electricity is fast approaching and in some cases exceeding their supply capability.

This situation can be improved by enhancing or upgrading the electrical infrastructure. Unfortunately, this can have both a negative economical and environmental impact. An alternative approach is to operate the existing system smarter by monitoring power system quantities and taking automatic control decisions and action based on the state of the power system. This methodology is often referred to as System Integrity Protection Schemes (SIPS).

This approach has gained momentum of late due to the enhancements in power system monitoring equipment; such as phasor measurement technology, faster communications networks and the development of decision making strategies in intelligent electronic devices (relays); such as fuzzy logic.

INTRODUCTION

For many Network Operators the challenge to balance supply against demand, securely within statutory limits is becoming increasingly difficult. This has been exacerbated by the move from radial systems to meshed, bi directional power flow networks. This increase in demand and changing network operating philosophy is pushing the power system stability limits, plant thermal ratings and causing issues with protection settings and applications. Unless necessary action is taken, the aforementioned will ultimately result in frequent losses of supply or "black outs" as witnessed over recent years.

It is possible to improve the situation with an enhancement or upgrade of the existing electrical infrastructure. Increasing its supply capability with the introduction of new power lines and/or increased generation can help. Unfortunately, this approach is often not favorable due to the adverse economical and environmental impact. An alternative approach is to operate the existing system smarter by monitoring power system quantities and taking automatic control decisions and action based on the state of the power system. Such systems are often referred to as System Integrity Protection Schemes (SIPS). SIPS can include Remedial Action Schemes (RAS), Special Protection Schemes (SPS), Operational Tripping Schemes (OR) as well as more commonly recognised schemes, such as under frequency / under voltage load shedding and out of step protection.

Fortunately, along with the increasing demand for electricity, there has been a considerable technological enhancement both in intelligent electronic devices and communications. The introduction of accurate monitoring of phasors, high bandwidth and faster communications networks, decision making strategies such as fuzzy logic and adaptive protection we are now better positioned to enhance SIPS to meet these network challenges.

SYSTEM INTEGRITY PROTECTION SCHEMES (SIPS)

The North American Electricity Reliability Council (NERC) defines a SPS or RAS as an automatic protection system designed to detect abnormal or predetermined system conditions and take corrective actions other than and/or in addition to the isolation of faulted components to maintain system reliability. Such actions may include changes in demand, generation or system configuration to maintain system stability, acceptable voltage or power flows **[1]**

Application of SIPS

Traditionally, in order to employ a SIPS it is necessary to carry out a system study, the results of which would then be used to design the SIPS. The study would provide information on the most appropriate action to take based on a set of predetermined conditions. Such conditions or "rules" are often held in a central location and information such as circuit breaker status used to determined the appropriate action. In some cases this can simply be a look up table. Following a fault and associated protection trip various transmission lines or generators are switched in and out of service based on the balance of plant in operation at the time. The actions are predetermined and can be varied by network control and once activated they become automatic. However, it is worth noting they are reactive not proactive.

One convenient method to classify SIPS control principles is by the scheme input variables that detect system contingencies and disturbances:

- Event- Based (directly detects outages and/or fault events and initiates actions such as generator/load tripping – this is open loop control
- Parameter-Based (measures variables for which a significant change confirms the occurrence of a critical event. The direct method is used to detect remote switching of circuit breakers and significant sudden changes which can cause instability, the measured values may include power, angles etc.
- Response-Based (monitors system response during disturbances and incorporates a closed loop process to react to actual system conditions. Under frequency and under voltage load shedding could be interpreted as response based closed loop schemes
- Combination of the above. ***[2]***

A vast number of SIPS are in operation worldwide, some of the most common are listed below:

1. Adaptive protection – changing protection settings based on system conditions
2. Generator control and rejection
3. Load Shedding
4. Out of Step Protection / Loss of Synchronism
5. Load rejection – transmission line removal
6. VAR compensation
7. System split / separation.
8. Open Line Detector
9. Dynamic Line Rating
10. Local Instability Detection

Considerations for the Implementation of SIPS

Based on the criticality and strategic importance of some schemes it is important to ensure that they are secure and reliable. Therefore extensive system studies must be carried out prior to employing the scheme. Issues such as duplication, redundancy and security must be considered. It is also important to understand the limits of the scheme when it comes to commissioning since the SIPS can have an impact on the wider system if maloperated during testing. Unfortunately, a SIPS is often employed or extended following an incident or a known operational restriction and thus bolted onto the existing protection and control scheme. Since the scheme will often involve connections to existing primary plant it may never to possible to test and commission the whole scheme, particularly if system outages are not possible. Even though the advances in communications may allow us to expand the boundary of SIPS from substation to wide area (this will be discussed later) commissioning and testing of such schemes will become more difficult due to the increased disruption it would cause to test the whole scheme.

Application of SIPS to Wide Area Protection & Control (WAPAC) schemes

In theory a SIPS can be employed at any level of the power systems, for example:

- Substation: information obtained locally within the substation and used to control the system in the immediate vicinity.
- Local Area: This will monitor a larger area and have an impact on a greater geographical area.
- Wide Area: This will monitor across a large geographical area and have the greatest impact.

The one common denominator in all of the above is the collection of data from remote points within the network and the transmission of that data to another point for analysis. Once the data is analysed the result is either passed to the operator at central control for manual action or passed back out to the field for automatic action. The more complicated the scheme i.e. as you move from Substation Level to Wide Area the more the demand on the communication network due to the increased level of data. The speed, bandwidth and reliability of the communication system becomes increasingly important. One of the major limitation of SIPS`s to date is the communications infrastructure. In the past, limitations in communications speed and bandwidth have resulted in SIPS operating as local, reactive, non time critical systems. This is due to that fact that it takes too long for the information to be commuted to a central point and thus has limited proactive dynamic applications such as stability angle control over a wide area.

The use of Ethernet based, fiber optic, large bandwidth communication systems such as IEC61850 utilizing GOOSE to transmit data from the field back to central control will have an impact on the response time of SIPS and thus improving their performance and application.

SIPS and the use of Phase Measurement Units (PMU)

Fast communication networks are essential when SIPS are applied in WAPAC schemes, since measurements of power system quantities in different parts of the system are required to be synchronised in order to be accurately compared. The use of Phasor Measurement Technology

(PMU) allows real time measurements to be taken with precise time synchronisation, thus accurate data comparison over a wide area as well as real time measurement based control actions are possible. The measurements are taken from strategic positions in the power system by (PMU`s) – these devices in conjunction with GPS provide time synchorised vectors. This information is then passed to a Phasor Data Concentrator (PDC) using a recognized communication protocol such as C37.118. The PDC can then analyse all the information from a number of PMU`s in the field and take appropriate action.

As reliance on the communication system grows and data is gathered from an expanding geographical area i.e. outside of the substation – the selection of communication system becomes more and more important. As well as architecture, protocol, redundancy, speed, bandwidth etc, it is important to look at cyber security since misuse of such schemes can have a dramatic and far reaching affect on the power system.

Detection of change in system topology is a strategic function for utilities, allowing them to plan their system defense for severe contingencies such as a loss of corridor situation.

Enhancements in IED (Relay) Technology

New protection devices have been developed which use fuzzy logic for their decision-making, thus making them adaptive to power system events.

Fuzzy Logic

Fuzzy sets take linguistic descriptions which are imprecise, such as "Nil", "Low" and "Normal", and convert them into membership values. As an example, if at 12 noon you were asked to say whether it is day or not, you would say “yes”. At 12 midnight you would say “no” – the answer to these two questions is in effect a binary logic result. However, if the question were asked at daybreak or dusk, the answer could be “kind of” – and fuzzy logic allows us to represent this as a fraction, maybe it is 0.5 (50%) daytime, or some other logical value between zero and unity. By reinforcing the decision making with multiple logical probability calculations, precise state determinations can be made.

Fuzzy Logic Applications

Fuzzy logic devices are available for open line detection on transmission systems ("DLO"), out of step detection ("RPS") and local instability detection at a generating station ("DLI"). The devices operate stand-alone, without any communication signaling from a remote station. This way they can be fast and dependable, taking remedial actions to prevent unwanted conditions such as transient overvoltages. The DLO device detects opening of a transmission corridor at a local or remote end breaker. The RPS notably offers predictive out of step, detecting early as the condition is developing, but before a slip occurs. The DLI is used to detect an imbalance of generation versus load, and hence can reject (trip) a generation excess.

CONCLUSION

It is widely understood and recognised that change`s to the way we think about and operate the electrical power network is required in order for the electricity supply to keep track with demand. We should take into account; economical, environmental, technological factors, grid architecture and components etc, when making operational decisions for both existing and future electrical power networks. As this paper details, it is not always necessary to go for the high cost, high environmental impact options to meet our requirements. Enhancements in communications, intelligent electronic devices and sound Engineering design practice can assist us in ensuring we meet the challenging operational constraints of future power grids.

BIOGRAPHY

Mr. John Wright is the Applications Manager at ALSTOM Grid Substation Automation Solutions in Stafford UK. He is currently responsible for technical, commissioning and applications support into the UK & Northern Europe. In addition to this, he holds the position of ALSTOM Grid Senior Expert in power system protection. Since graduating from Staffordshire University in 1991 with a first class honors degree in Electrical Engineering he has held various positions relating to Power System Protection and Control. He is a Chartered Engineer, IET Fellow and active member of the CIGRE working group B5.

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