# The Reality of Providing Energy in Australia: Bushfire Mitigation and the Benefits of Power Quality Monitoring Outside Substations

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***Abstract* - Utilities operating in Australia face many adversaries with regards to power distribution; challenges which would drive most international counterparts to alternative markets. Australian utilities are a much more resilient group, and with modern developments in pole mounted switchgear, the obstacles faced are not quite as insurmountable as they used to be.**

**Australian utilities possess among the longest feeders in the world, and long feeder lines exacerbate the issues presented with power quality and bushfire risk, but with recent developments in capabilities of automatic circuit reclosers (ACRs), it is possible to alleviate this headache. Further updates to recloser control capabilities have caused the advent of remote ACR power quality monitoring, and this new capability has opened the door for greater reliability on long feeders as more accurate, local and relevant power quality data can be gathered. All of this information can be remotely interrogated, retrieved and then manipulated to grant utilities unprecedented resources to improve their reliability of supply. Additionally, new capabilities to control and manipulate reclosing sequences remotely without having to edit settings along with simple self-diagnosing communications systems to ensure reliable network reporting and awareness, it is possible to reduce and manage the bushfire risk.**

**This paper outlines the recent developments in bushfire mitigation strategies through the use of pole mounted ACRs, specifically the NOJA Power RC10 system. Additionally, the application use of remote Power Quality data gathering using the NOJA Power RC10 system is discussed. Recent developments in the capability of data capture from this recloser system allows for a greater understanding of network performance to be formed. This information can be used to improve network performance and financial bottom line for utilities by optimisation of their currently installed resources.**

## I. Introduction

THROUGHOUT Australia's electricity supply history, utilities have grappled with some unique issues. Australian utilities are known for innovation, and the utility demands placed on manufacturers have been responsible for some of the greatest steps in switchgear development. As one of the largest interconnected networks in the world, distribution network service providers (DNSPs) in Australia face big issues presented by the unique geography and climate.

One of the greatest causes for concern in the Australian Distribution community is the aspect of bushfire risk. Australia has a long history of bushfire disasters, but in lieu of the devastating events of February 2009 the impact of utilities has been burned into the Australian psyche. The resilience of Australia's utilities and engineers prompts appropriate development to mitigate these risks, and this paper outlines some of the features available using one of the most common protective distribution switchgear devices: the automatic circuit recloser (ACR).

ACRs humble beginnings as hydraulic devices in the mid-1900s has evolved greatly through the years through to semiconductor controlled switches. These switches have proliferated across networks all over the globe, driven by the immediate reliability benefits and protection offered on a reasonable budget. Australia itself has had a fair share of manufacturers, and today there are thousands of NOJA Power reclosers in service providing reliability to customers.

Driven by continuous requirements from utilities, these semiconductor controlled reclosers have been greatly developed, and this paper presents some solutions implemented to combat the challenges of the Australian distribution network. Bushfire mitigation is at the forefront of development, and through use of the NOJA Power RC10 control system it is now possible to update and integrate bushfire mitigation strategies using commissioned NOJA Power assets, with a simple firmware update and a network integration strategy.

By using the on board voltage and current sensing capabilities of these reclosers, the RC10 now has the capability to conduct complete power quality monitoring and reporting – a technology long bound to the granite yards of substations. This functionality is now available out on the feeders, using the exact same protection devices installed years ago, providing power quality feedback from the shores of the gold coast to Uluru.

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## II. USING RECLOSERS TO PROVIDE BUSHFIRE SOLUTIONS

Bushfire risk is a fundamental issue of concern for most Australian utilities, with events such as the February 2009 bushfires in Victoria being blamed on a local utility resulting in lengthy court proceedings and fines. As responsible DNSPs, all utilities are interested in mitigating their risk of causing fires. Recent developments in recloser technology allows for the simple integration of bushfire risk management strategies using the current install base of NOJA Power Reclosers.

Recloser strategy for system reliability basically relies on interrupting faults, and restoring supply after a specified open time at the recloser. A reclose sequence may have multiple different close attempts, but from a bushfire mitigation standpoint the more reclose operations in a sequence, the greater the risk of ignition at a fault point on the feeder. Whilst for low fire risk days a longer recloser sequence will result in less customer lost minutes, the multiple reclose attempts will each increase risk of ignition.

Previous strategies implemented in recloser schemes involved complete disabling the reclose functionality on bushfire risk days. This can be achieved by remote SCADA control, and toggling of the global control of the recloser converting it essentially to a single shot circuit breaker. This practice compromises the economic performance, and is a brute force method of addressing the risk of bushfire ignition. It is far more elegant to have a remote capability to modify the reclose sequence, by applying global controls which can be toggled to reduce the length of the reclose sequence in different ways, without completely compromising system performance like using the "Auto Reclose OFF" method.

Figure 1 outlines a basic four shot to lockout reclose sequence which is typical of a low fire risk recloser system. From this figure, it is possible to see that there is a variation in tripping time and dead time associated with each step in the reclose sequence. By granting the capability to selectively remove portions of the reclose sequence, it is possible to customise the performance of the recloser to match a particular bushfire mitigation need.

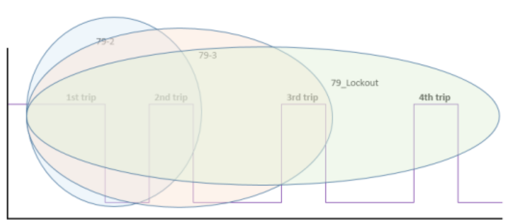


*Figure 1: Reclose Sequence*

NOJA Power has worked closely with utilities to establish global control points for the recloser system which will allow for the mitigation of bushfire risk. The outcome of this development are the following global control points:

- 79_2 and 79_3 Lockout
- Short Sequence Mode
- Disable Fast Trips
- Maximum Number of Trips

The ANSI standard for protection defines 79 lockout as being a protection interruption of a fault current. Since the maximum trips to lockout in the C37.60-2003 standard is defined as being 4, the inclusion of two new control points known as 79-2 and 79-3 lockout to the recloser control allows for blanket changes to the reclose sequence without actually having to change internal settings. 79-2 and 79-3 lockout are global controls which limit the reclose sequence in the device to the first two and three reclose operations respectively. Figure 1 demonstrates the effects of 79-2 and 79-3 lockout. When these points are set to off, the device returns to its usual configuration. By applying these points on bushfire risk days, the risk is greatly minimized, all whilst using a simple process which can be easily integrated into a switching scheme and protection configuration.

79-2 and 79-3's reclose sequence reduction capabilities are very effective, but they are quite limiting with regards to which steps to remove. The subject of recloser timing for each protection step merits a paper of its own, but for the purposes of demonstration there exists a philosophy of "fault burning" and "fuse burning" using reclosers. As reclosers are capable of withstanding fault current for short periods of time, some reclosing philosophies intentionally include a slow trip response point in the fault sequence. This allows the lines and recloser to attempt to "burn" a resilient fault away, such as a branch fallen across parallel overhead lines, or an unfortunate possum or bird suffering the same fate. Obviously intentionally starting fires to attempt to improve reliability is a poor practice during high risk bushfire periods, and this raises the requirement for an additional control point to remove other points in the reclose sequence.

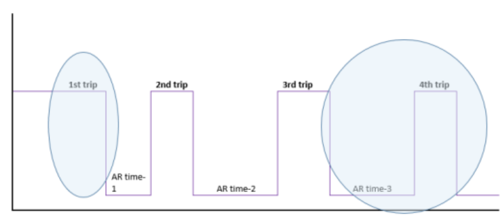


*Figure 2: Short Sequence Mode*

Figure 2 demonstrates the solution to this issue, known as Short Sequence Mode. Unlike 79-2 which chops off the end recloser sequence to reach a limit of 2, Short Sequence Mode's global control point causes the recloser to use only the first and last part of the sequence. This functionality has applications to both a 3 and 4 shot to lockout capability and it provides controllers with the capability to make all different changes to the reclose sequence without actually having to manipulate settings. SSM is also available as a SCADA control point, and the network integration method is exactly the same as per the 79-2/79-3 functionality.

Disable Fast Trips (DFT) is an additional global control which allow an operator to directly remove their fuse burning implementation using a single control point. Similarly to the other control points, this is an after effect on the reclose sequence, and does not edit the internal settings configuration, but it allows for removing and enabling of the fuse burning strategy of a recloser with one point control. Understanding the relevance of disable fast trips requires an understanding of the proprietary reclose map implementation in the RC10 system, but essentially the OC2 element is solely responsible for the fuse burning/saving strategy. DFT allows for a global disable of OC2, even if the setting is configured, to allow for removal of the strategy. Figure 3 outlines the DFT effect zone. Maximum Number of Trips (MNT) is purely a logic link between environmental factors and the existence of a fuse burning strategy. MNT examines the number of nuisance trips over a period of hours, and if the threshold is exceeded MNT will automatically disable the fuse burning strategy. This logic allows for automation of risk mitigation on high fire risk/high wind days, where pecking faults such as a tree blowing up against a line could cause ignition over constant fault events over the course of a day.

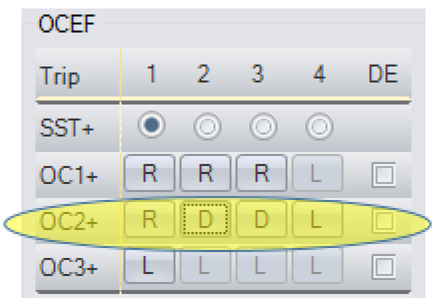


*Figure 3: OC2 and Disable Fast Trips (DFT)*

Finally, all of this protection modification is only as good as the communications method which supports it. Whilst the RC10 has an onboard RTU like most good recloser controllers, the reliability of the communications between the SCADA Master station and the recloser is the key in the reliability and bushfire mitigation capabilities outlined above. Good IT practice involve periodically resetting remote communications peripherals, but if a connection is lost the remote device might not be able to receive a reset command.

With this in mind, a communications watchdog was implemented within the RC10. This communications watchdog monitors incoming SCADA traffic, and checks to see if communications with the master station has been lost. There are two indicators which the watchdog examines, the binary control points, and the master station polling. The watchdog within the controller will cause the communications peripheral to reset if no binary control commands have been received within a certain window, and additionally to reset the communications peripheral if no master station polls have been received within a certain window of time. This allows the recloser to attempt to restore communications automatically when communications are lost, saving time and money when successful and reducing risk to utilities.

Through embracing these controls, utilities can seamlessly integrate simple bushfire risk management schemes into their current fleet of NOJA Power Reclosers. The logical step forward then is to evaluate the power quality at these sites, to examine the effects of bushfire risk mitigation strategies and to establish areas of concern for the network.

## III. Power Quality

Power Quality is an important concept to understand in modern electrical service provision. By ignoring this issue, we allow opportunity for devastating harmonics to freely travel through our networks, destroying our assets and interrupting our customer service. Only through protection and monitoring of these issues will it be possible to improve network performance, safety, reliability, and economic bottom line.

New developments in reclosers allow for comprehensive Power Quality monitoring and protection features using the current install base. These reclosers now have the ability to measure Harmonic Distortion, Interruptions, and Sags and Swells, and it is important to develop an understanding of these features for optimum use of the resource.

### *A. Harmonics*

Within a Power Transmission System, all power is delivered at a set frequency, which in Australia is 50 Hz. Harmonics are “contaminants” within the power supply, which have a frequency which is a multiple of the baseline or “Fundamental” Frequency. These contaminant harmonics enter the power system through many different means, but ultimately the bottom line is they are a nuisance, and should be protected against.

Harmonics on the network can be devastating. Since these harmonics are essentially carrying unusable superfluous energy across the network, they put excess strain on any devices connected. These harmonics cause damage to insulation and the very power electronics which cause them, along with excess transmission losses. The major issue is that harmonic damage is insidious. There are usually very limited symptoms of harmonic issues, until a catastrophic event such as the loss of a transformer or motor, which usually is accompanied by an inherent fire risk. These risks are something which DNSPs are taking a great interest in, and in Australia the harmonic limit of contamination is limited as low as 8% at the point of common connection, it is our responsibility in the energy industry that harmonics are prevented from travelling through the network. And this in turn means that any responsible DNSP needs to be able to provide protection against these damaging harmonics.

The single greatest cause of harmonics within the power system is the results of the semiconductor. Most modern loads which use some sort of power electronics to transform the grid energy to usable energy for the device cause harmonic distortion. This is a result of what is known as “Non Linear current draw”, meaning that the devices do not take in the full natural sine wave. There are other causes, such as transformer saturation, or large industrial loads such as Arc Furnaces, or even fluorescent office lighting. Additionally, the large scale installation of solar photovoltaic arrays and their semiconductor inverters are a notorious source of harmonics. With the proliferation of power electronics into the network, it's easy to see how a minor issue of the past is becoming progressively more prevalent as technology advances.

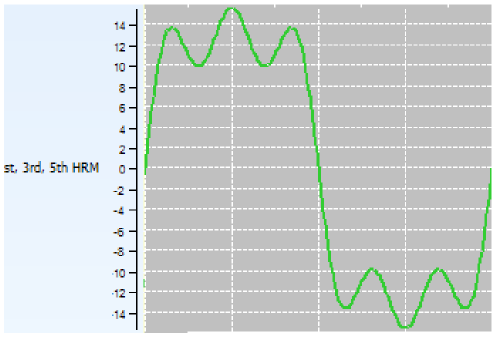

*Figure 4: A Waveform with High Harmonic Content*

Simplicity of calculation is lost when starting to consider harmonics, which is the initial challenge of interpreting harmonic content. Whilst these unattractive waves look terribly complicated to understand, there are two major mathematical ideas which make the concept quite simple. These are:

- The Principle of Superposition
- Fourier Transforms

The basic idea is that any complex wave can be represented as a sum of individual simple waves. This is the concept of superposition. Fourier Transforms are the mathematical method for working out what these individual waves are. The main difference between these waves are their magnitude, and their frequency – which just so happens to be the two main features of harmonic identification.

Harmonics are waves which have frequency multiples of the fundamental frequency. Since any complex wave can be represented by a combination of these waves, it is then possible to understand what the harmonic content of a power supply is. The RC10 system utilises what is known as a "Fast Fourier Transform" or FFT algorithm to analyse the energy flowing through the device, to provide exact values for both the harmonic frequency and its magnitude.

Harmonics are measured in two separate methods, known as Total Harmonic Distortion, and Total Demand Distortion. THD is a ratio between the fundamental voltage wave, and all the voltage harmonics. This is expressed as a percentage. Total Demand Distortion is calculated in a similar way, except the ratio is based on the peak current demand, rather than instantaneous voltage used by THD. TDD is used to calculate current distortion relative to the peak demand.

The NOJA Power RC10 uses FFT algorithms to guarantee protection against the first through the fifteenth harmonic of the device, and allows for specific allowed limits of up to five of these individual harmonics. The system records all the data for the harmonics within a separate log file, which can be analysed to determine the power quality flowing through the device. The RC10 allows for user configurable response times to harmonics, for both THD and TDD. All the information required in order to calculate harmonics and provide protection is achieved through use of the inbuilt voltage sensors and current transformers within the recloser. The raw values are passed through the FPGA of the controller for parsing, and protection and monitoring is executed on the calculated results. This method allows for all OSM reclosers in service to provide this additional functionality with no development cost. The only cost to an end user is the process of implementing a data management scheme to follow the implementation.

Within the RC10, the actual evaluation of harmonics is conducted through dead band monitoring. This means that a harmonic record is logged each time the system deviates out of a dead band. This method is similar to DNP3 analogue monitoring, and as such should be tweaked according to the individual requirements of the DNSP. A dead band too small will result in excess data, but too broad and there will be important transitions missed.

*B. Interruptions*

One of the greatest indicators of power quality issues is the measure of customer minutes lost. This value is obviously of high interest to DNSPs as it directly relates to their economic bottom line, but it is now possible to actually calculate feeder performance at an RC10 controlled recloser. Again, by using the currently installed asset, it is much simpler to implement data gathering like this across a larger install base whilst minimising the cost impact.

The RC10 allows for user configurable settings to determine the difference between a short and long interruption and can log all the information relevant to each of these interruptions separately. Conveniently, the total time of interruption and all customisations to the metering can be read and configured from the HMI panel on the device, along with a simple option to transfer all the field logs to a USB to be analysed at the utilities discretion. Interruption tracking essentially fills the data void left by our own protection systems. If a fault occurs which causes a loss of power to a customer, the device will track the time. Our power quality management tool also has the capability to use this data to calculate performance index values, such as SAIFI, SAIDI and MAIFI.

*C. Sags/Swells*

Sags and swells are characteristic of the ebb and flow of power system as the energy demand shifts through the day. In times of low demand, the end user voltage can begin to creep up, and vice versa. Just like the interruptions monitoring, sag and swell monitoring fills the data void left by our overvoltage and under voltage protection. Also, since it evaluates a smaller deviation, data which is usually missed by protection levels is still recorded. Sags and swells can be indicators of greater issues present in the network, and also allow utilities to better prepare for the mitigation of ill effects caused by periods of overvoltage and brownout. Sags and Swell gathering is implemented in similar fashion to interruptions monitoring in the RC10, however instead of looking for periods of loss of supply, a comparison is made between the registered system voltage and the witnessed voltage. Event durations are also captured and timestamped, allowing utilities to understand what the trends in voltage are during the course of days or weeks.

### *D. Oscillography*

The final piece of the monitoring puzzle is to actually capture a direct copy of the current and voltage waveforms passing through the recloser. By directly capturing the waveforms, a wealth of possibilities for analysis, interpretation and network improvement are provided. As the reclosers already possess all measuring devices required as well as the capability to interpret all data at a high sample rate, it is a logical extension to be able to plot this data in the IEEE format of COMTRADE. This oscillography data can then be retrieved and imported into many different software packages for analysis.

In order to capture data that is worthwhile, it is important to be able to trigger the correct capture point. This depends greatly upon the installation, but selecting the correct prefault capture and trigger point is paramount in effective use of this technology.

One of the most interesting applications of this technology is to capture fault events at reclosers, and import these COMTRADES into relay test sets such as an Omicron or Doble. These test sets allow for simulation of the real faults present on a network, granting the capability for evaluation of performance of network assets, along with the optimisation of network protection.

### *E. Remote Retrieving of Data*

All power quality data including oscillography gathered from the NOJA Power RC10 can be gathered remotely. Given the challenges of geographic distribution within Australia, many DNSPs have progressed towards an engineering access approach to managing their smart reclosers. By using this same port on the RC10 reclosers, it is possible to remotely gather the PQDIF and COMTRADE files from the reclosers.

These logs can contain years of performance data, and through using a software package such as Power Quality Software™ from NOJA Power it is possible to filter and evaluate the information gathered.

In keeping with more traditional SCADA readings, most functionality mentioned for power quality within this paper has associated SCADA Binary and Analogue points, allowing for instantaneous readings of Harmonics, Sags/Swells, and interruption data. Through using familiar methods of data gathering, integration of power quality monitoring into an existing recloser network can be seamless and simple.

## IV. Conclusion

The only way to guarantee a continuous improvement in network performance is to embrace the new technology on offer. This paper outlines the new capabilities available within an asset which already is in use across the majority of Australia. Through bushfire mitigation and power quality monitoring, it is possible to grow the performance and revenues of DNSPs, and in a time where efficient, safe network operation is paramount it is negligent to disregard the capabilities available within the switchgear of choice on distribution networks, the semiconductor controlled ACR.