Online Integration of SCADA with Network simulation tool

A KALKI white paper

Revision 1.0
Version 1.0

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Introduction

This document covers the integration of a distribution network simulation tool with a SCADA (Supervisory Control and Data Acquisition) package. Such an integrated solution will constitute the central component of a DMS (Distribution Management System). Additional capabilities of the DMS arising from such integration will prove vastly beneficial to the power distribution company enabling them to enhance their delivery model. In the first part of this white paper we will look at the typical architecture of such a solution. In the second part we shall briefly cover the details of a pilot project done by KALKI in this domain. Lessons and insights learned from the pilot project will form the concluding section of this paper.

Almost all DMS will have a SCADA package and a network simulation tool (NST) as its components. In most of the cases, the former will constitute the center stone of the whole DMS suite. Several additional software components such as customer information system, billing system, outage and maintenance management system etc. will be integrated to the SCADA package to constitute the entire DMS. NST however is typically not integrated with the SCADA and is run as a stand-alone package (often in a separate PC/network/location than the other solutions). Network data available in SCADA such as topology information, protective devices installation, load distribution and load growth data etc. is also replicated in the NST. However this updating is done in an offline manner and in relatively long intervals (such as weeks or months).

In such an offline fashion the NST is used for planning purposes. Utilities of the NST in this role would include network planning, contingency analysis etc. For example, planning engineers can simulate a fault or other contingency in the network and gauge how the same affects different parts of the network. Similarly they can add additional load (consumers) to multiple zones in the network and analyze the subsequent behavior of the distribution network. In addition to these “what-if” capabilities, a typical NST will also provide some optimization features. This may include identifying the optimum placement location for a new capacitor bank (or other protective/reliability devices). The NST may also allow users to identify the optimal equipment (such as OH cables or transformers) for different sections of the network. However all such analysis and optimization capabilities provided by the NST acts on network that is static and offline.

The purpose of this document is to see if additional benefits can be realized if the NST can perform these actions in an online fashion. We will also see how a typical NST (which is primarily designed to work with offline data) can be adapted to function in an online fashion.

Benefits of an Online NST

As we saw in the previous section an NST works with offline, static data. In such a role the NST proves beneficial for network planning and optimization. By making the NST online (integrating it with the field through SCADA) we take the solution from the planning room to the operations room. Here it provides near real time solutions and optimizations to events as and when they happen in the field. Some of they key benefits ensuing from this online integration include:

- Enables operator to respond to events in real time: By integration with SCADA the operator can assess the effects on the network of a field event in near real time. This assessment (along with the contingency management options available in the NTS) will allow the operator to respond to the field event in a more informed manner and in relatively shorter time.

- Enables replaying of field events in “what-if” studies: In an offline mode data updating from field to NST happens in an infrequent manner. As a result, a relatively small sample of the events from the field is updated to the NST database. Transient events or other events that are perceived “minor” by the operator will fail to make it to the NST database. In the case of an online integration each and every captured by SCADA is transferred to the NST leading to a more meaningful and comprehensive utilization of the network simulation tool.

- Enables automation of routine tasks: It may be required of the network simulation tool to run several tasks and analysis in a periodic fashion. This might include running the network connectivity analysis module whenever the topology of the distribution network changes. Or it might be the need to run a load flow analysis in a periodic fashion and listing the sections that may be facing under voltage or overload issues. In an online system such routine tasks can be triggered as and when required i.e. in response to a SCADA event or at definite time intervals.

- Additional reports and offline data: Most network simulation tools provide a wide array of report that provides analysis results for individual sections corresponding to load flow or network connectivity analysis. Reports of such extensive nature and for individual sections may not be available with SCADA. Continuous and full-fledged transfer of SCADA data to NST will thus facilitate the generation of such extensive reports.

The upshot of the above points is that online integration of NST with SCADA will allow the operations to maintain a better balanced and managed distribution system that can respond to faults and contingencies in a much faster and efficient manner.

How the integration can be brought about?

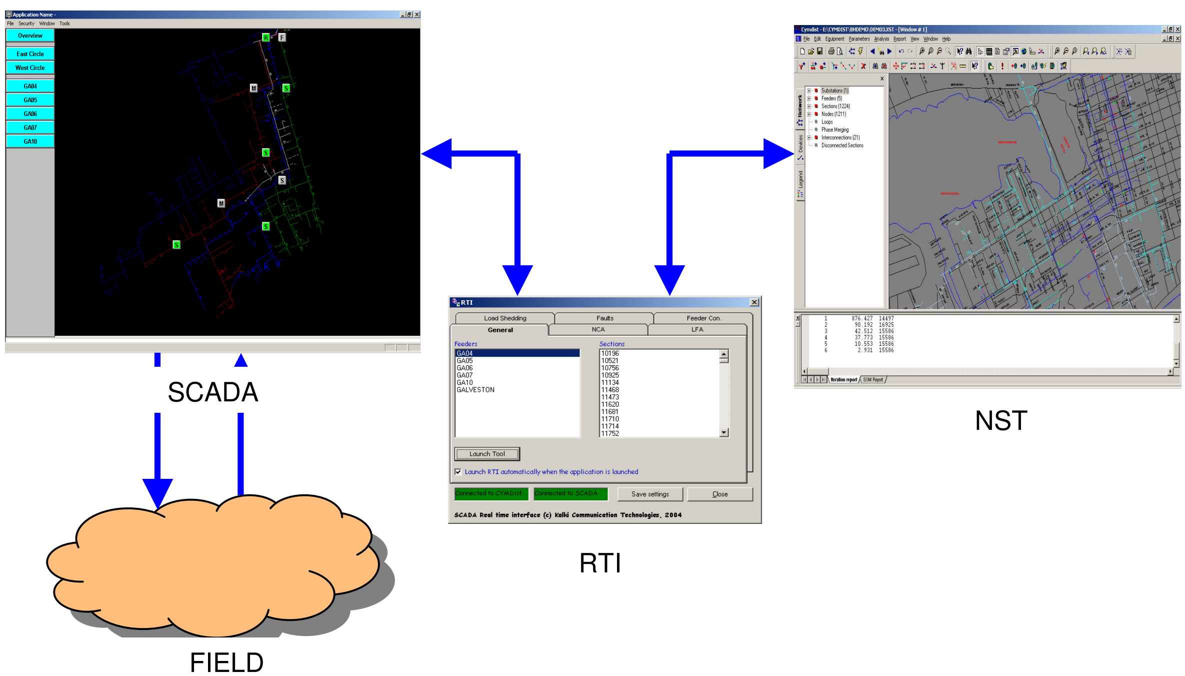
From the above discussion it is clear that the crux of the integration lies in transferring of field events from SCADA to the NST. The data to be transferred include analog values (such as voltage or load values available at different metering locations) and digital values (such as on-off status for protection or isolation devices such as switches and relays). In a similar fashion, after the analysis or optimization at the NTS end, the data need to be transferred back to the SCADA. Such data will typically consist of some device operations such as switching on a capacitor bank to remedy an under-voltage situation or isolating a section by turning off a switch etc.

Typical SCADA package will have multiple communication interfaces through which such communication can be handled. Some of these mechanisms include an OPC (OLE for Process Control) interface, a DDE (Dynamic Data Exchange) interface etc. Other communication protocols may also be supported by the SCADA (such as Modbus protocol) through which this communication can be facilitated.

Similarly, at the NTS end also some interface has to be provided for interacting with the software so that field data from the SCADA can be taken in and analysis and optimization result can be sent out. Some of the NTS packages available in the market facilitate this interaction through a programming interface (API) such as COM. Others allow for such communication by passing on data as flat text files. In very few instances, standard communication interfaces such as OPC or DDE are also available with NTS packages allowing for much tighter and simpler integration with SCADA. Apart from this interface for data exchange, the NTS should also allow for its methods (such as analysis) to be invoked through an external interface (i.e. other than the Graphical User Interface – GUI – provided by the NTS package). Where a COM interface is provided, this option is readily available in the form of functions or procedures that can be invoked in-process or out-of-process.

Software architecture for the integration

A typical representation of the software architecture to bring about an integrated NTS solution is given below.



In the architecture diagram above, the SCADA is responsible for fetching the data from the field. Even in the online NST solution, there are no modifications at the SCADA end i.e. no specific design or development is required while implementing or configuring the control and monitoring solution to accommodate the online NST component. At the NST end minimal configuration changes may be required. Primarily this would be to ensure that the data exchange and communication interface is enabled at the NST end. The additional configuration may be required where such interfaces are add-on or optional modules. In case these interfaces are part of standard features, no special effort is required at the NST end either.

In addition to these standard packages, a third component viz. RTI (Real Time Interface) constitutes the solution. RTI acts as the central coordinator facilitating the online integration of NST with SCADA. In this role the RTI is responsible for the two-way communication of data, events and results between SCADA and NST. The RTI is also responsible for invoking appropriate methods of the NST for analysis, report generation. Since the RTI was developed and tested as part of the pilot project exercise, this module will be discussed in further detail in the next section.

Pilot project on online integration of NST

This section of the paper briefly describes a pilot project that was done by KALKI for demonstration purposes. The objective of the project was to perform a quick and simple integration of an NST with a SCADA package to demonstrate the communication mechanism and to highlight the real time response that is possible with such a system. The software components used for the pilot project were

NST: CymDist (a software that "…simulates distribution networks to aid planning…") from CYME International was used as the network simulation tool. In addition to its extensive features, a critical advantage offered by CymDist was the COM interface it provided for external programs to invoke its methods.

SCADA: Webstudio from Indusoft was used as the SCADA package.

RTI (Real Time Interface) was developed in-house by KALKI. For the pilot project, this was developed as a simple Visual Basic program that talks to InduSoft at one end and to CymDist at the other.

Features covered in the project

Critical features demonstrated as part of the pilot project are listed below:

a) Ability to transfer network topology change events from the field to NST
b) Ability to run load analysis frequently with updated load values from the field
c) Transferring switching optimization results from NST to field through SCADA

a) <u>Ability to transfer network topology change events</u>

Network topology change occurs in a distribution networks due to operation of switches and other protective devices. For the pilot project two devices viz. switches and relays were considered. When the status of a switch (or relay) is toggled in SCADA (through operator action or in response to field events such as faults), the same is simulated in NST. The SCADA and NST have to share the same network model for this purpose. The location (equipment id) of the toggled switch and its current status is passed from SCADA to NST. NST will simulate the same action (on/off) for the same device in its network model. Following this the network analysis module in the NST will be triggered by the RTI. Thus the state of the complete distribution network following the protection device action will now be available to the operator on the NST. Problem sections (such as those which face under voltage) can be identified and remedial actions taken if required. If the topology change has occurred subsequent to a fault, restoration plan for the system can also be prepared. All reports from the NST associated with the network analysis are generated automatically subsequent to the analysis.

b) <u>Ability to run load analysis automatically</u>

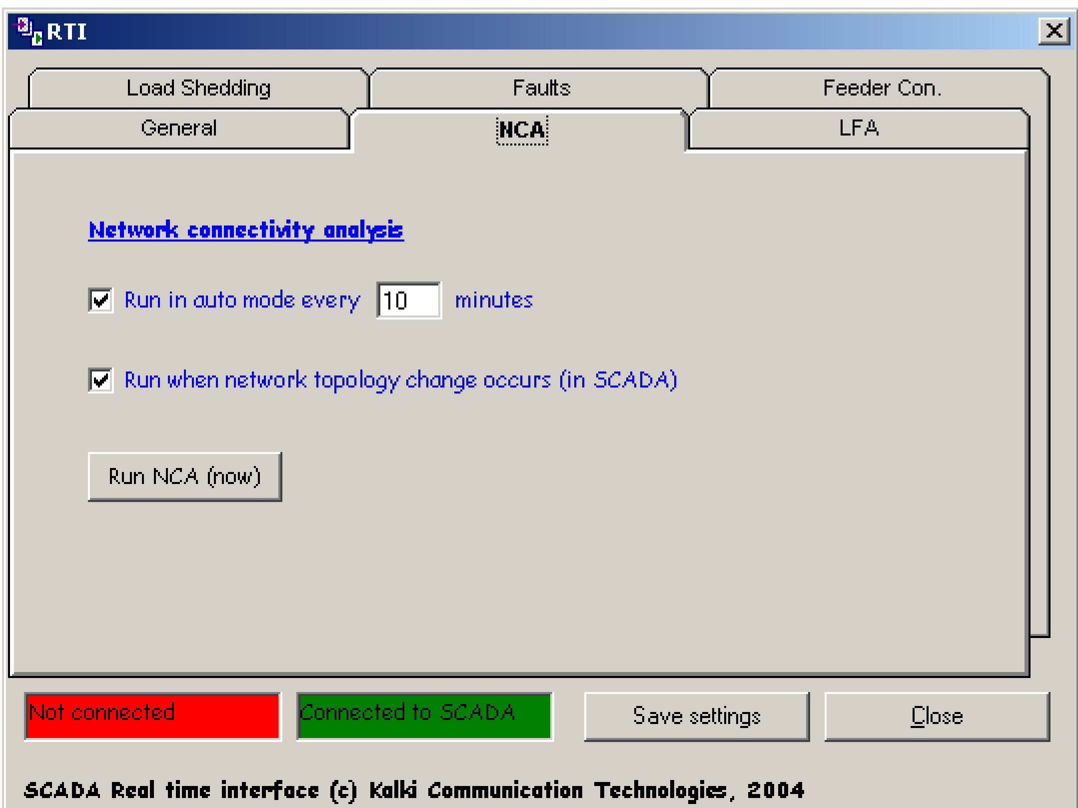
Another feature that was simulated was to invoke the load flow analysis feature in NST automatically. This was implemented through the RTI. The load flow analysis could be invoked in a periodic fashion or subsequent to specific events in the field. Prior to each load flow analysis, load values from relevant points on the network (metered points such as feeders, transformers, switches) can be transferred to the NST. Thus load flow analysis of the distribution network will happen with the updated load values. The NST is capable of pointing out overloaded locations in the network as well as providing an array of detailed and summary reports regarding the load flow. This will provide valuable real time information to the operator, enabling optimal management of the network.

c) Transferring switching optimization from NST to SCADA

A third critical feature implemented in the pilot project was the option to transfer switching optimization results from the NST to SCADA (and from there to the field). Given an objective such as minimizing KW losses or attaining load balance between feeders, the NST can solve the network equations and come up with an optimal switching sequence that can help attain the specified objective. In the pilot project it was made possible for the RTI to transfer this switching sequence recommendation from NST to the SCADA. This feature while sparing the operator from manually reproducing each of the switching operation in SCADA also demonstrated the two-way communication capability (i.e. from SCADA to NST and then NST to SCADA) of the integrated system. This feature also allowed for an operator verification stage before the switching recommendations were transferred from NST to SCADA. This mechanism was provided to prevent switching operations being carried out in the network inadvertently.

Real time interface (RTI)

As already mentioned, RTI is the crucial component of the integrated system enabling the offline NST to be converted to an online one. This was also the only additional component developed as part of the pilot project. In this section, therefore, we will take a close look at RTI.



RTI facilitated the two-way communication between SCADA and NST. For this purpose it had two communication interfaces – on one side it communicated with SCADA using the interface(s) supported by the SCADA vendor. On the other side it talked to the NST through its COM interface. The RTI also acted as a listened for SCADA events. Whenever distribution network changes were reported in the SCADA (such as topology changes), the RTI would trigger a sequence of steps. Firstly it would collect all the network change data (for example, switches or protection devices that acted during the network change) from SCADA and pass the same on the

NST. Secondly it would invoke the required analysis routine in the NST. Once the analysis is completed, it would bring the NST interface to the front so that problem areas and analysis reports are brought to the user attention.

RTI was also responsible for automating routine tasks without operator intervention. For example, it might be required to call the load flow analysis or the network analysis in a periodic fashion. A scheduling feature for invoking such tasks was not available with the NST. The RTI provided this scheduling interface and invoked the required NST methods through the COM interface as and when required. Similarly another requirement was to carry out load shedding operations in the distribution network subject to a set of rules and constraints specified by the distribution network operator. This translated to determining and executing a set of switching actions so that load would be shed subject to the specified conditions. RTI was used to implement this functionality since the same was not supported by the NST or SCADA. RTI would determine the switching sequence required for shedding the load and would send the same as a series of instructions to SCADA. NST did not have any role to play in the implementation of this feature.

As already discussed, RTI was also used to transfer switching recommendations from NST to SCADA. Once the switching optimization analysis was carried out by the NST this would be available as a report to the operator. RTI would allow operator to open this report and validate the switching recommendations given. Upon operator confirmation the switching operations would be passed on to SCADA as a series of commands. This method has the advantage that operator can modify on the switching recommendation given by NST before transferring the same to SCADA.

Limitations for the pilot project

In this section we will enumerate some of the shortcomings of the pilot project carried out. These shortcomings, in our perception, do not undermine the value of the project since the basic objectives of the project were met quite successfully. This section is provided so that the reader can better assess the limitations of the conclusions drawn from the pilot implementation:

i) The network model used for the pilot project was not an extensive one. It contained one substation, five distribution feeders and associated switching and protective devices. An actual distribution network is likely to be much larger with multiple scores of substations and hundreds of feeders. The communication mechanism for the integrated solution (including the volume of data to be handled) need to scale up for such a huge network. This kind of volume could not be demonstrated as part of the project.

ii) The distribution model used for the pilot project was not part of an actual network, but rather a modeled one. This is to say that a hypothetical distribution network consisting of a substation, five feeders and several sections and loads was constructed. The impact of this on the pilot project is likely to be very minimal, however. This because the distribution network modeled was not very off from a real one. However since the modeled network was a purely radial one, the conclusions from the same may not be applicable for a ring topology.

iii) To cut down on the development time and effort, the RTI was developed in a simple and “dirty” fashion. Visual Basic was used as the developed language and a simple communication architecture based on DDE (Dynamic Data Exchange) was followed. In our opinion, this architecture would need to be considerably improved upon before it can be used for a live distribution network.

iv) All possible devices and operations possible in a distribution network was not covered for reasons of time and economy. The devices covered included relays, meters and switches. These were selected since they affected the network topology and load distribution in their operations. A full-fledged capability demonstration project should perhaps cover all the devices that may be possible in a distribution network.

v) Similarly all possible operations in the NST were not covered as part of the pilot project. Feature covered include network connectivity analysis, load flow analysis, switching optimization, circuit tracing, identifying loops and parallels etc. As for the previous point a full capability demonstration should address the complete functionality of the NST.

Major lessons from the pilot

Having put the above rider on the limitations of the pilot project, let us now look at what was actually gained from the project.

i) Firstly and most importantly, the pilot project was able to demonstrate the concept at hand successfully. That is, the possibility of and benefits from the integration of a network simulation tool with a SCADA package was demonstrated. It was shown that data could be exchanged from the field to the simulation tool in near real time providing great benefits to the operator in the optimal management of the distribution network.

ii) Two-way communication between SCADA and NST was demonstrated. Using the RTI it was shown that data could be transferred from SCADA to NST and NST to SCADA. This was done with existing interfaces available with the respective packages without any sort of customization.

iii) On the SCADA end of the communication interface generic mechanisms available from the SCADA (such as DDE/OPC) was used. This makes it possible to use any SCADA package in such an integrated architecture. This would also make it possible for existing DMS packages to be enhanced by adding an online network analysis tool without the need to rework on existing hardware and software installations.

Suggestions for further work

In the course of the pilot project, we stumbled upon some points that can be useful for future implementations of this concept. They include

i) Use OPC (OLE for Process) control for communication. Having completed the pilot project we felt that OPC would be the most suitable mechanism for communication between RTI and SCADA. The kind of data that needs to be exchanged between RTI and SCADA, volume of data to be handled and the handshaking required in the interfacing mechanism – all are adequately supported by an OPC interface without undue complication.

ii) Use XML for network model exchange. For the online solution, it is required for the network topology to be transferred from SCADA to NST. We felt that available XML standards such as CIM XML would be ideal for the purpose.

iii) Better communication interface at the NST end. Ok, this is a wish list rather than a recommendation. We feel that existing network simulation packages have not been developed with such a full-fledged integration in mind. If the NST end of the architecture can support additional integration mechanism, it would make the life of the developer for such an online solution much simpler.