A NOVEL MICROSCADA SYSTEM FOR MIDDLE EGYPT ELECTRICITY COMPANY

M.Ghaly, *Middle Egypt Electricity Company (MEECO), Minia City, Minia, Egypt, Tel: 20 86 346-733, Fax: 20 86 353-517*
M. Riad Ghononemy, *Engineering office for Integrated Projects (EOIP), Maadi, Cairo, Egypt, Tel: 202 525-0386, Fax: 202 525-0375*
Ahmed El-Bialy, *Systems and Biomedical Dept., Faculty of Eng., Cairo Univ., Cairo, Egypt, Tel: 202 570-3420, Fax: 202 525-0375*
A.Hisham Kandil, *Systems and Biomedical Dept., Faculty of Eng., Cairo Univ., Cairo, Egypt, Tel: 202 570-3420, Fax: 202 525-0375*
H.A.Darwish, *Electrical Engineering Dept., Faculty of Eng., Menoufiya Univ., Menoufiya, Egypt, Tel:2048 221-549, Fax:2048 238-531*
M.M. Ali, *Middle Egypt Electricity Company (MEECO), Minia City, Minia, Egypt, Tel: 20 86 346-733, Fax: 20 86 353-517*

SUMMARY

The supervisory control and data acquisition (SCADA) system became a popular part of the power system automation and has been extended to cover miscellaneous applications even in small size foundations. Historically, most of the automation efforts have been directed to serve the generation and transmission systems and a little attention has been given to the distribution system. That is because of problems which mainly have technical nature associated with the distribution system. These problems are attributed to the high number of scattered sites to be supervised by the master controller. These sites cannot be covered using either narrow band Radio Signals or telephone lines. The distribution Line communication (DLC) can be considered an efficient alternative communication medium to the aforementioned ones. The main advantage of the DLC is that the same distribution feeders are used as carriers for the communication signals. Therefore, the problems of scattered sites, distance, and the narrow band of the communication signal can be overcome.

Modern digital relays (DRL's) are designed to provide protection functions along with the intelligent remote terminal units (RTU) acquisition and data recording. Numerical relays are performing overcurrent, differential, distance … etc protection function based on the acquisition of system voltage and current values. Also, relays can provide event and Oscillography recording with a time stamp of high resolution. Therefore using numerical relays, a sensible reduction in the RTU size can be produced and further reduction in the capital cost of the SCADA system is obtained. In distribution level, numerical overcurrent relays are common and utilizing relays adapted to provide the RTU feature would be beneficiary to the SCADA system. The aforementioned considerations are taken into account during the development of the proposed microscada.

In this paper, a cost effective microscada system for Middle Egypt Electricity Company is presented. The novel system has been fully commissioned at El-Mermah switching panel, MEECO, Egypt. The proposed microscada is based on hierarchical control principle where it can be integrated to a higher level sub-master SCADA and even with grand master SCADA. The uniqueness of the proposed microscada is accomplished by achieving the followings:

a) It achieves a low level monitoring and control at the Distribution point (DP).
b) It employs a full power DRL's instead of the RTU's with no extra cost.
c) It replaces the RF communication with the DLC to reduce the SCADA over all cost.
d) Using the DLC extends the capabilities of the proposed microscada to cover higher number of scattered sites (kiosks).
e) It extends the capabilities of the principal of SCADA to reach lower level of nodes, not achieved before (kiosks and consumers)
f) It is based on hierarchical homogeneous modules that can be integrated to cover all DP's and extended to form a higher supervisory SCADA.

The proposed microscada system consists mainly of:

a) Digital overcurrent relays (DRL's) adapted to provide protection, monitoring, metering and controlling function in addition to the RTU functions.
b) DLC module, in which the data is collected from remote location (Kiosks) and then forwarded to the higher control level. A transformer intelligent module (TIM) is installed at each kiosk to collect the transformer status and send it to a data collection and control unit (DCC) through the DLC
c) The sectionalizer is used to locate and isolate the fault over the distribution rural line and sends the fault status allocation to the microscada through the DLC.
d) Automatic meter reading (AMR) in which the meter readings are collected remotely on periodical-basis by a receiver (Rx) unit installed at each kiosk. Then, readings are transmitted serially to the TIM to be ready for DCC request.
e) The microscada server is located at the distribution point (DP). It contains dual redundant DCC's, which collect the data from the Transformer Intelligent Modules (TIM). However, the DRL's data and commands are sent serially to the DP's servers (usually PC) via RS485. Also, the DP PC collects the rings data from the DCC's via another RS485 serial port.
f) A higher level of control (sub-master) is usually located at the substation (optional), where, the SCADA server is used to interface a LAN to the Integrated Service Digital Network (ISDN) or leased lines with proper redundancy to all DP's microscada computers. Thus, the overall view of the communication medium is therefore converted into Information Technology (IT) network. The proposed arrangement allows the microscada at the DP's to perform local monitoring, and controlling of the DP's elements. Details of microscada modules are given in the full paper

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ABSTRACT

In this paper, a cost effective microscada system for Middle Egypt Electricity Company is presented. The novel system has been fully commissioned at El-Mermah switching panel, MEECO, Egypt. The proposed microscada is based on hierarchical control principle where it can be integrated to a higher level sub-master SCADA and even with grand master SCADA. The proposed microscada is responsible to collect data of the main modules like the Digital overcurrent relays (DRL's), Distribution line communication (DLC) modules, automatic meter reading (AMR), and sectionalizers on regular basis and send the data to the sub-master station for supervisory monitoring and navigation. In addition, the sub-master can allow the microscada level to control the modules locally. A full detail description of microscada design, communication protocols and field results are given. The test results validate the microscada system for its effectiveness together with the reduced cost.

Keywords: *Microscada, SCADA, Numerical relays, Power line communications, Power control system, and Distribution automation*.

INTRODUCTION

The supervisory control and data acquisition (SCADA) system became a popular part of the power system automation and has been extended to cover miscellaneous applications even in small size foundations. Historically, most of the automation efforts have been directed to serve the generation and transmission systems and a little attention has been given to the distribution system. That is because of problems which mainly have technical nature associated with the distribution system. These problems are attributed to the high number of scattered sites to be supervised by the master controller. These sites cannot be covered using either narrow band Radio Signals or telephone lines [1,2]. The distribution Line communication (DLC) can be considered an efficient alternative communication medium to the aforementioned ones. The main advantage of the DLC is that the same distribution feeders are used as carriers for the communication signals. Therefore, the problems of scattered sites, distance, and the narrow band of the communication signal can be overcome.

Modern digital relays (DRL's) are designed to provide protection functions along with the intelligent remote terminal units (RTU) acquisition and data recording [3-4]. Numerical relays are performing overcurrent, differential, distance … etc protection function based on the acquisition of system voltage and current values. Also, relays can provide event and Oscillography recording with a time stamp of high resolution. Therefore using numerical relays, a sensible reduction in the RTU size can be produced and further reduction in the capital cost of the SCADA system is obtained. In distribution level, numerical overcurrent relays are common and utilizing relays adapted to provide the RTU feature would be beneficiary to the SCADA system. The aforementioned considerations are taken into account during the development of the proposed microscada.

DESCRIPTION OF THE PROPOSED MICROSCADA

The uniqueness of the proposed microscada is accomplished by achieving the followings:

a) It achieves a low level monitoring and control at the Distribution point (DP).
b) It employs a full power DRL's instead of the RTU's with no extra cost.
c) It replaces the RF communication with the DLC to reduce the SCADA over all cost.
d) Using the DLC extends the capabilities of the proposed microscada to cover higher number of scattered sites (kiosks).
e) It extends the capabilities of the principal of SCADA to reach lower level of nodes, not achieved before (kiosks and consumers)
f) It is based on hierarchical homogeneous modules that can be integrated to cover all DP's and extended to form a higher supervisory SCADA.

The proposed microscada system is described using Fig.(1,2) The system consists mainly of:

a) Digital overcurrent relays (DRL's) adapted to provide protection, monitoring, metering and controlling function. Each relay acts also as an intelligent RTU to communicate with the microscada and to record the major events of the feeder current oscilligraphy.
b) Distribution Line communication (DLC) module, in which the data is collected from remote location (Kiosks and switching panels) and then forwarded to the higher control level; sub-master. A transformer intelligent module (TIM) is installed at each kiosk to collect the transformer status and send it to a data collection and control unit (DCC) through the DLC. Based on the collected data, feeder losses, efficiency,

load power factor, fault location … etc. can be determined and displayed by the microscada software. Both TIM's and DCC are coupled to the low voltage side of the distribution transformer.

c) The sectionalizer is used to locate and isolate the fault over the distribution rural line and sends the fault status allocation to the microscada through the DLC. One unit only has been employed in this pilot project that had provided 50% of the desired reliability of the 11kV line.

d) Automatic meter reading (AMR) in which the meter readings are collected remotely on periodical-basis by a receiver (Rx) unit installed at each kiosk. Then, readings are transmitted serially to the TIM to be ready for DCC request. Also, the commercial losses at each transformer is measured through the AMR system and transmitted to the DCC.

e) The microscada server is located at the distribution point (DP). It contains dual redundant DCC's, which collect the data from the Transformer Intelligent Modules (TIM). However, the DRL's data and commands are sent serially to the DP's servers (usually PC) via RS485. Also, the DP PC collects the rings data from the DCC's via another RS485 serial port.

f) A higher level of control (SCADA sub-master) is usually located at the substation (optional), where, the SCADA server is used to interface a LAN to the Integrated Service Digital Network (ISDN) or leased lines with proper redundancy to all DP's microscada computers. Thus, the overall view of the communication medium is therefore converted into Information Technology (IT) network. The proposed arrangement allows the microscada at the DP's to perform local metering, monitoring, and controlling of the DP's elements.

Details of each element of the microscada modules are given in the following sections.

DESCRIPTION OF AU0S RELAY

The superior performance of numerical relays has been proven and the application of these relays for protection purposes has been reported [3]. The relay functions have been extended to do control actions. The automation unit with serial communication (AU0S) is a novel digital overcurrent relay developed to provide the protection, control, metering, monitoring and RTU functions using one hardware module. The protection functions of the relay time characteristics are selected based on the British and IEC standards. The real time implementation of the time functions is performed based on the integration principles to insure consistent response during fault current dynamics. The relay hardware is based on multiprocessor architecture and arranged in three modules. These are input/output, main controller, and communication modules. The hardware is optimised seeking to produce cost effective product. Several features have been provided to make the proposed relay superior in its protection and control performance. For example, the false operation of the overcurrent relays during inrush periods is blocked using the harmonic threshold associated with the line and transformer energization. Also, true rms and fundamental rms metering would reflect the actual loading level of the feeder and percentage of harmonic content.

The relay is equipped with four methods to communicate with. These are keypad and display in the front panel for easy access by the operator, RS232 for PC communication, RS485 for SCADA communication, and infrared for remote communication with hand set units. Accessing the AU0S by hand set is considered the most simplified method for the field in case that SCADA is not installed. The design principles and priority determination between these communication methods are decided such that keypad, infrared, RS232, and finally the RS485 in descent order. In order to insure accurate time synchronisation according to new control requirement [4], a stand-alone hardware module is developed and its firmware is based on the IRIG-B standards (with amplitude modulated type). Time resolution between different relays in the switching panel is to be in the order of 1 millisecond. With this time precision, events and oscilligraphy are recorded and retrieved for further fault analysis. Also, the relay uniquely accepts full setting and configuration form the four communication methods including the SCADA. Various control functions are provided to AU0S to simplify the remote opening and closing of the breaker to fulfill the operation purposes. In addition, the breaker thermal capacity during interruptions is accumulated and accounted for by AU0S. The relay also provides full supervision on the breaker operations and detects all abnormal operations.

The basis for AU0S algorithms, hardware and firmware details, time synchronization circuit, and field test results are to be given in a separate publication [5].

MEDIUM VOLTAGE DLC SCHEME

The DLC can be considered an efficient alternative communication medium to be used in the distribution level. The transmission lines, cable cores, or cable sheath if exists are the carriers of the communication signals [1,2]. The DLC signals are usually injected to the MV feeders via inductive or capacitive coupling. DLC systems, which adopt the injection of communication signal from the low voltage side of the distribution transformers, are more attractive than other schemes, since, no additional equipment or device such as MV capacitor is required to couple the communication signal to the medium voltage. Also, the transformer Δ/Y connection would be helpful in coupling the communication signal to the three phases.

The DLC scheme is terminal access network of the proposed microscada system in this pilot project. Data collection and command sending to the TIM's units are conveyed through the medium voltage (MV) DLC system. The main communication units (TIM's & DCC's) are inductively coupled with the MV feeder via existing distribution transformer. All distribution transformers at MEECO are 3-phase 11/0.4*kV*, iron core type, Δ/Y earthed connection, and having ratings from 10*KVA* to 1*MVA*. These ratings can be considered suitable for MV-DLC applications. The communication signal is injected into one phase only of the low voltage side of the distribution transformer. Then, the distribution transformer transfers it to the 3-phases of the medium voltage feeders. This would provide the desirable path redundancy. Utilizing this proposed assembly of DLC system would substantially reduce the expected cost of the system to about 60% of other alternative systems.

For simplicity purposes, the communication can be viewed as two-way link between two transceivers; one at the kiosks (TIM) and the other at the microscada (DCC). Each unit consists mainly of three modules. These are power supply and power amplifier, DLC modem and intelligent input/output modules. The bit rate of this system is 100 bit/sec. This rate is apparently small, however compared to the data size required from each kiosk, it is a quite sufficient one. The carrier frequencies are allocated at midpoints between the power frequency harmonics. This limits the modulation bandwidth for these carriers to an order less than 50 Hz. However, as there is a large number of these carriers available in the transformers pass band, frequency division multiple access can be conveniently used to allow full time availability for each communication node instead of the conventional party-line polling scheme used with RF channels. This bit rate per carrier with full time availability is sufficient for the largest DP.

The data collected from each kiosk is one 8-bit word sensed by the digital input/output module in addition to the available meters' data via RS232. The 8-bit word is a general purpose and it is devoted to collect the status of the fault indicator, MV load break switch, and LV sub-sorter(s) status. However, data received via the RS232 include kwhr, watt, var, and power factor meters installed in the kiosks. In this project, only the kwhr reading has been collected from the available electromechanical meter. The meter has been provided with LV transmitter module. Details of the design of the TIM and DCC units and impact of the distribution network on the DLC signal is to be published in separate publication [6]

SECTIONALIZER SCHEME

The insertion of automatic switches (sectionalizers) controlled by an intelligent logic controller in the distribution line would involve a substantial improvement of the transmission selectivity and reliability. Sectionalizers are proposed to replace the manual switches and operated in coordination with an automatic reclosure. The sectionalizer controller is enhanced with a transceiver (reprogrammed TIM) to communicate with the distribution point DCC. The sectionalizer intelligent input/output has the ability to detect if the branch is faulted or not via continuous monitoring of the fault indicator contacts. Thus when a fault occurs, the autoreclosure clears it instantaneously and the fault current is brought down to zero. A specific routine is applied to insure that the fault is permanent and the minimum faulted area has been determined before isolation. A communication sequence between the sectionalizer TIM and the distribution point DCC is incorporated to collect the fault indicator status. Then, the microscada generates automatically an off signal to the particular sectionalizer that isolates the minimal faulty area during the off-line part of the autoreclosure cycle. Therefore, no breaking current capacity is necessary for the sectionalizer.

AUTOMATIC METER READING

Automatic meter reading (AMR) in which the customer meter readings are collected remotely on periodical-basis by the receiver (Rx) installed at each distribution transformer kiosk. AMR requires the installation of a transmitter in each meter. The AMR system has been applied in a landscape level in different Egyptian distribution companies and its accuracy has been proven. The LV communication signal between the meters' transmitter and the Rx is based on the spread spectrum technique. Spreading the signal over a wide bandwidth helps combating nulls in the frequency response of the channel that is usually present in the LV distribution network. That is due to the random nature of the network. Detail of the spread spectrum system design has been reported in [7,8].

The readings collected by the Rx are transmitted serially to TIM which forwards them to the DCC to be included in the database of the microscada for further billing system flexible operation. Also, the collected data would be beneficiary for determination of the commercial losses at each transformer.

MICROSCADA FEATURES

The followings are the main features of the SCADA system [9-11]:

- Acquisition, processing, monitoring, and recording of remote terminals data, substation status, protection alarms, analog measurements, …etc.
- Monitoring of fault indicators.
- Telecontrol.
- Sequence of events recording with time stamp.
- Power system studies of network operation, network configuration, load flow, short circuit calculations and load forecasting.
- Integrated add up module

MICROSCADA FUNCTIONS (SOFTWARE)

The following SCADA functions are implemented in the pilot project.

1) Data Acquisition

The data to be collected at sub-master site of the SCADA system should include:

I. ***Status Indication***

- ON/OFF status indication of the 11 kV and 33 kV circuit breakers.
- ON/OFF status indication of the 11 kV feeders isolating switches if exists.
- ON/OFF status indication of circuit breakers.
- Status indication of Remote/Local control mode

II. ***Protection Alarms of both substation and Dp's***

- Over current relay trip on incoming and outgoing of both substation and DP and outgoing feeders.
- Earth leakage relay trip on incoming outgoing and out going feeders.

III. ***Alarms of both substation and Dp's***

- Under voltage of both substation & DP's battery.
- Station battery charger failure
- 220 volt AC loss.
- Communication equipment failure.
- Fire alarm.

IV. ***Analog Measurements***

- MV and 33 kV bus bars voltage in the substation imported from the relays.
- Phase currents of MV and 33 kV incoming feeders in the substation.
- Phase currents of MV outgoing feeders in the substation.
- Active and reactive power of MV outgoing feeders in the substation.
- Bus bars voltage in the DP.
- Phase current of outgoing feeders in the DP's.

The above analog measurements are to be performed by the numerical relays and transmitted to the DP's personnel computers.

2) Telecontrol

Supervisory control is the process of actuating equipment operation at remote locations. The process includes selection of the station, selection of the device to be controlled, and execution of the desired command such as OPEN or CLOSE. Correct selection and operation is critical to the safety of personnel and the security of the electric system. For this reason some form of select-verify selection-operate sequence or for short, "check-before-operate" method is employed.

A Remote/Local control switch will be provided and installed in each distribution point and substation.

3) Monitoring and Event Processing

I.***Status monitoring:*** Status indication should be monitored and presented to the operator

II. ***Limit value monitoring:*** Feeder loading and bus bar voltage measured values should be monitored against upper and lower alarm limits with dead bands. When the measured value exceeds such limits an event should be generated and presented to the operator.

III.***Information display:*** Information display is the process of selectively retrieving both fixed and real-time data from the database, combining, and presenting them to the operator, in the form of graphics user interface pages. The fixed data include information that is non-varying in time. The variable data include status of the two or three state devices, and analog values which vary in magnitude and possibly sign. Unit designations and point identification by name or ID number are considered fixed values and are appended to the variables.

IV.***Event processing:*** Events generated by the alarm function shall be presented to the operator, processed, grouped and classified before they are stored in the database.

Alerting the operator to unscheduled events and informing him of the time of occurrence, the station location, the device ID, and the nature of the event is generally referred to as alarm processing. The output of the alarm processor is chronological CRT alarm lists, hardcopy printouts, and audible alarms. Some form of alarm acknowledgment by the operator shall be provided.

4) Information Summaries and Reports

The SCADA historical file provides an excellent source of information for the production of various reports. These reports, their formats and information content, satisfy the specific needs of a wide variety of end users.

The followings are some categories of the reports that are provided.

Information Summaries:

That includes event and general alarms lists, Selected event lists (off normal list) i.e. list of all measured quantities out of normal limits and all equipment out of normal state and faults statistics.

Reports:

They are either hardcopy reports of CRT display or Periodic pre-defined logs.

Daily report shall include:

That includes hourly load for each feeder (Amp.). Hourly load for each substation or distribution Point. Peak load for each feeder. Peak load for each substation or distribution point. Peak load for the monitored power system and system daily report.

Weekly reports:

That includes Daily peak load for each feeder. Daily peak load for each substation and distribution point. Alarm summary including a chronological log of all alarms in separate list for each alarm type. These lists are indicating time, location and time of acknowledgement.

Monthly reports:

That includes daily peak load for each feeder. Daily peak load for each substation or distribution points. Monthly peak of the monitored system.

Energy count for each feeder. Energy count for each substation or distribution point. Snapshot of all feeders' load and bus bars voltage at the time of system monthly peak (averaged over 15 minute period).

The aforementioned information summaries and reports should be stored for later retrieval. The database should accommodate temporary and long-term changes. Selected information should be automatically displayed, while all information summaries and reports should be CRT displayable and printable on demand.

5) Sequence of Events Recording

Sequence of Events (SOE) is the process of capturing and recording unscheduled events to a time resolution independent of the periodicity of microscada server polling by the master station. Company uses digital relays with oscillographic recording of analog voltage and current captured before event occurrence. An accurate time base or clock within the DRL is fundamental for SOE recording. Time resolution of recorded events should be in the order at ± 10ms. The DRL time clocks are periodically synchronized by transmission of a time code message from a possible global positioning system (GPS) module, located at the DP station to the relays IRIG-B port. The sequence of events at a given DRL is transmitted to the microscada station where they are chronologically ordered with events received from other locations at the sub-master and then printed as one combined listing, or presented on CRT chronological lists.

6) Time Parameters

The time parameters in the normal system activity level [15% of the system inputs changing every ten (10) seconds and operator display request each thirty (30) seconds] is:

– Response time for operator entry **0.5 sec.**
– Response to a Telecontrol (change of state) **1 sec.**
– Overall time between the operator actuation of a control command and the status input associated with that control respond on the CRT **3 sec.**
– Response to display request command (Single Line Diagram, Table, … including real-time data) **1 sec.**
– Overall transfer time of a C.B change of state **4 sec.**
– Overall transfer time of lower priority alarms **2 sec.**
– Age of measurements **60 seconds**

In case of heavy system activity [40% of the system inputs are changing every ten (10) seconds and an operator display request each ten (10) seconds], response to display command may be relaxed to three (3) seconds and age of measurements may be extended to two (2) minutes.

7) Fault Location

The provided system should be capable of locating the faulty section in 11 kV cables sections feeding the distribution transformers stations (Kiosks) in urban areas as the first stage of an integrated fault location, isolation and restoration system.

MODE OF OPERATION

The microscada in the DP has three working operating modes; local, remote and normal. In the local mode it doesn't accept remote commands from higher-level SCADA (Sub-master). In the remote mode, the microscada at the DP does not respond to local commands. Finally, in the normal mode it accepts and responds to local and remote commands. Switching between modes is controlled with extreme precautions.

DATA PROCESSING AND COMMUNICATION

The microscada applies two communications strategies. It collects data form the DRL's and Tim's utilizing periodic polling scheme. While it reports-by-exception to the higher-level sub-master. Therefore, it utilizes both benefits of the two schemes without scarifying any of both advantages.

POSSIBLE EXTENSIONS TO THE MICROSCADA

– Increasing the number of the distribution points covered by the microscada
– Connectivity of the microscada with the master station
– Evolution of the microscada to a full-featured SCADA
– Monitoring of the lighting system for maintenance purpose

CONCLUSION

The paper has presented a full description of a cost effective microscada system for MEECO. The system was implemented, as a pilot project to test and verify the idea of building this cost-effective microscada. Full commissioning of the system has been lunched at El-Mermah switching panel, Bani Swief Section, MEECO, Egypt. Figures 3,4 and 5 show some screens of the microscada system. The system also applies the DLC to reduce the overall cost to about 60% of equivalent major system. The system consists mainly of DRL's adapted to provide overcurrent protection and RTU functions. A TIM unit is installed at each kiosk to collect the transformer status and send the data to the DCC unit through the DLC. The collected data by the DCC is forward to the higher control level sub-master. Based on the collected data, feeder losses, efficiency, load power factor, fault location … etc. can determined and displayed by the microscada software.

An AMR is utilized to collect the kwhr meter readings remotely on periodical-basis and data is stored at the Rx, which is connected serially to the TIM. Then, readings are transmitted to DCC to be included in the database of the microscada. A sectionalizer is employed to locate and isolate the fault over the rural lines and sends the fault status allocation to the microscada through the DLC. The system is composed of two systems microscada and higher sub-master unit. The microscada is responsible of collecting data of the main modules like the DRL's, TIM's, and sectionalizers on regular basis and send the data to the master station for monitoring and navigation. The microscada modules, design, communication protocols, data testing and collected samples of the field results have been given. The test results have validated the microscada system.

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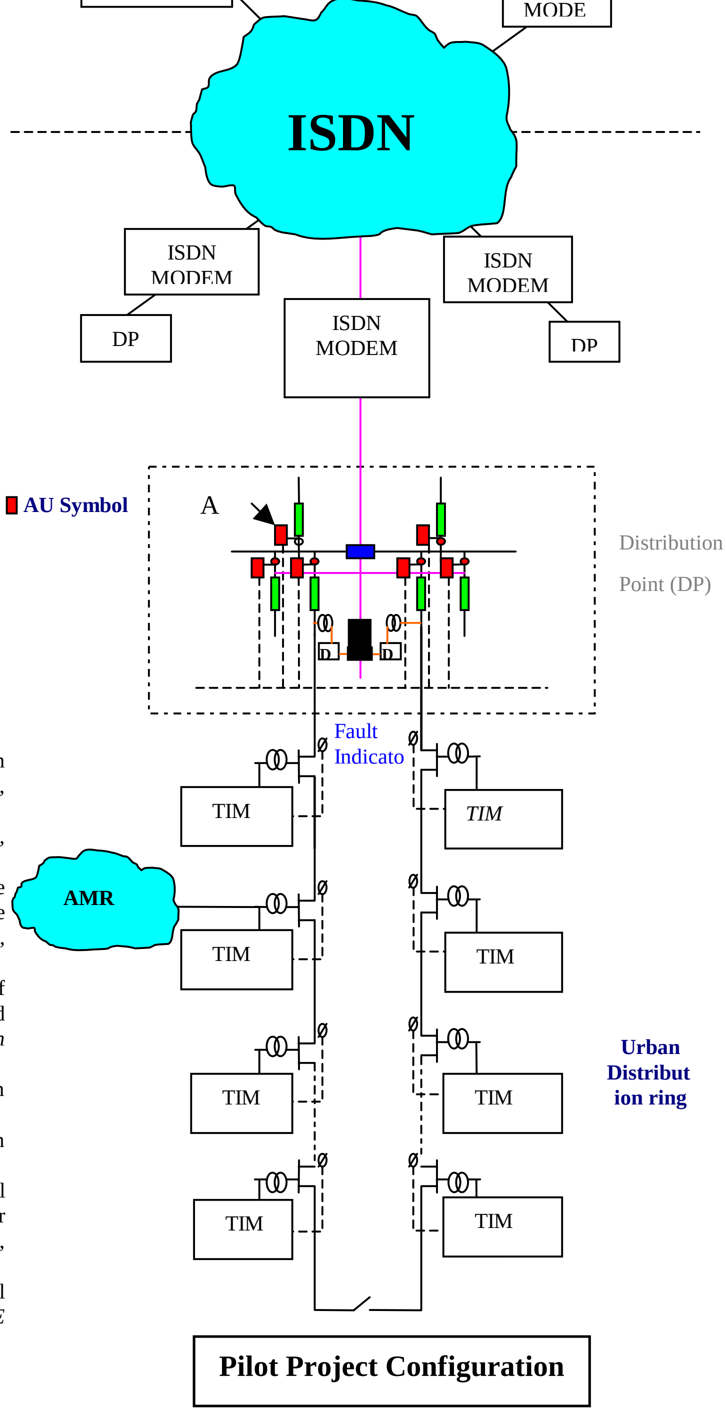

Fig.1 Microscada System