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OPTICAL FIBER TRANSMISSION MEDIA (OPGW) FOR A RELIABLE OPERATION OF THE TELECOMMUNICATION AND PROTECTION SYSTEMS ON HIGH VOLTAGE TRANSMISSION SYSTEM

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SUMMARY

The Communication systems, as well as the Protection systems are continuously requiring low figures of Unavailability by using a lot of techniques as follows: path protection of the communication links; duplicated systems; redundancy of the circuits of each equipment (double CPU; double power supply); using elements/components included in the circuits with certified lambda of the components; etc.

Additionally, the optical cables are the main link for being used by the digital communication systems in order to transmit the mission critical functions (differential protection system; teleprotection) as well as for transmission of the non-critical mission functions (SCADA, Ethernet networking for Protection Control System, Telephony, Video Monitoring of the electrical equipment, Video Surveillance of rooms/areas, etc). Consequently, the performance of the OPGW cables must be better and better reliable every time according with the Availability requirements.. Consequently and equivalently, it is essential that the optical cables will not be a node of Unavailability in the whole chain of devices/components of the Communication System and/or Protection System. The reliable functioning of High and Extra High AC Voltage Systems, as well as for DC High Voltage Systems is strongly dependent of the optical cable. It is important to take into account the OPGW cable must not consider as a conventional Ground Wire conductor of the High Voltage Line (HVL). It is necessary to take the precautions and pay special attention about the requirements, from the points of view of an optical cable: design, calculation, selection of manufacturer, tests, installation procedures, commissioning, etc. The topics that are described below are very different in an optical cable than in a conventional GW. Consequently, the requirements of a OPGW must be analyzed, projected, and designed with more high level of detail as well as a lot of precautions more than a conventional Ground Wire. It is fundamental that all topics must be discussed and agreed by both, the Communications Area and the HV Lines Area
The differential current needs an very reliable optical link for connecting the IEDs of both ends, in order to get a high Availability (Ai) for the join of "protection system + optical link". It is essential the resources of Network Management Systems (NMS), for: the communication system, protection system, and for optical cable.
It is essential to include the resources of Network Management Systems (NMS), for: *the communication system; *protection system; and *optical cable. The looking for high Ai figures will minimize the OPex due to:
*in a direct manner, by a reduction of operative costs
*in an indirect manner, by a reduction of future failures in cable and equipment
*by extending their useful period of time functioning correctly

KEYWORDS

OPGW, Availability, Attenuation, Wavelength, ACS, RTS, SCADA, teleprotection, differential protection, NMS

1. STAGES INVOLVED

The characteristics of the OPGW must be preserved along its whole useful life and not be only during the commissioning stage. Its maximum performance as well as the Unavailability minimum values will be obtained taken into account all the stages involved, as follows:

•Along the project and design stages

•Using international standards as:IEC60793/60794;IEEE1138;IEEE Std524;UIT-TG.652/657, etc

•During the process of selection of a experienced manufacturer

•Along the tests process, doing Type Tests and Factory Acceptance Tests: both for the entire cable as well as for its components/elements

•During the detailed engineering stage, looking for a integrated solution: the OPGW cable + its elements for installation / mounting (because they must function as A WHOLE)

•Along the installation process of the optical cable, through a specified procedure as established by the manufacturer of the optical cable; using a set of adequate tools for OPGW cables (that are not like the ones used for a Ground Wire installation); with process of automatic controls release; with a control of the direction of rotation of the cable; etc

•During the process of splicing of fibers, through an aseptic and clean room/vehicle; following standard processes;using high quality instrumentation set; done by experienced people, etc

•During the stage of commissioning it is necessary to do a precise/strict characterization of each optical fibers, in order to compare with the warranted data sheet that were relieved during the FAT process

•Conforming a "Referential Data Base" of the characteristics of the OPGW for future maintenance tasks as well as for being used during the whole useful life of the cable

•During the maintenance stage, by using a standardized procedures, with good instrumentation set and qualified people

The right and precise observance of each stages above mentioned will affect and will increase of Service Quality of the optical cable, because it will get:

•Reduction of catastrophic failures, by minimizing the eventual replacement of sections of cable, etc

•Reduction of period of out of service of the optical cable, by minimizing the figures of Unavailability of the transmitted functions along it

•Increasing substantially the useful life of the optical cable and getting an optimum performance for long periods of time

•Reduction of the OPex due to the minimal tasks for repair

2. FEATURES TO BE CONSIDERED

a) From point of view of the external metallic area of the cable, and depending of the characteristics of the HV Line, as well as the environmental conditions, it will analyse simple or double corona of wires in order to resist the mechanical stress during the installation process, as well as to resist the permanent stress of the final mounting arrangement.

Both, the amount and the type of wires to be used, must be chosen in order to: to permit and reduce the over-temperature due to the condition produced by the short circuit on the HV Line; to resist the atmospheric discharges of the zone with no damage on the individual wires or to assure a minimum residual stress of 75% of the Rated Tensile Strength of the whole cable.

It is recommended the RTS was be calculated at 90% of the maximum load of each individual wire and with no contribution of the metallic tube, according to IEEE 1138 item 3.2e)

The type of material of the wires should be chosen between the following combinations:

•Aluminium alloy (ASTM B415):

•Aluminium clad steel (ASTM B398)

The breaking load of ACS wires will allow to have installations with a reduced sag of the OPGW (greater tensile strength with low unit weigh, as well as lower solicitation on the structures of the HV Lines). It means to obtain wider spans and reduced distance between conductors.

b) In order to satisfy the requirements of atmospheric discharges must be specified the level of atmospheric discharges (Coulombs) according to IEC 60794-1-2 Table 2. The discharges can produce: full cut of some individual wires; partial damage of wires; damage of the metallic tube; damage in the tapes and other elements in the interior of the cables (affecting the protection of the fibers); etc

In order to resist the level of discharges it is necessary to take into account the combination of following parameters:

•Diameter of the wires of each corona

•Type of material of the wires
•Treatment of each wire
•Resistivity of the wires
•Maximum tensile strength of the wires
It is important to do a set of Type Tests to the optical cables according to IEC 60794-1-2 method H2, IEC 60794-4 -1 with the condition of tensile strength of 25% of the specified RTS (worst case of greater tensile of the cable during the discharge). According to concepts of design mentioned by IEEE 1138 standard
c) In order to get the requirements of the short circuit of the HV Line, it must calculate the energy to be resisted by the OPGW, considering:
•Short circuit current of the HV Line
•Fault clearing time (order of 250/300 mseg)
•Initial and final temperature of the metallic corona of the OPGW (Ti:40/50 ºC; Tf:160/180 ºC)
•Energy to be obtained (kA2.seg)
In case of the HV Lines with double ground wire, it must taken into account that the proportion of Icc/Ik that effectively is guided on the OPGW (partially by the traditional ground wire and partially by the OPGW)
The short circuit tests must verify the performance of the OPGW according IEC 60794-1-2 method H1, with conditions of 15% of the RTS (worst case of bigger movement of the cable along the test)
d) It is very important the anti vibration devices in the design and project of the OPGW cable, as well as for the rest of the mounting elements. Consequently, it is necessary to do a previous Vibration Study of the whole OPGW disposal, taking into account:
•Laminar airflow produced in flat geographic areas
•Galloping of the cable due to wind, detachment of ice, etc
•Adverse climatic conditions
•Arrangement of phase conductors
•Characteristics of the structures of the HV Line
As a result of the Vibration Study will be concluded: the type of stockbridge, the amount of them, the location of the stockbridges on the OPGW, etc
e) It is essential to take into account that the performance of the OPGW must be analyzed and projected under two aspects (both simultaneously):
*Immutability/non-alteration of functioning of the OPGW like ground wire function of the HV Line (mechanically and electrically)
*Immutability/non-alteration of the performance of the optical fibers that will be used both, by the communication systems and the protection systems (variation of attenuation, coefficient of PMD, chromatic dispersion, and other optic parameters)

5 ENERGETIC SOLICITATION OF THE OPGW CABLE

5.1 Criteria

In order to get the requirements of the short circuit in 500 kV overhead line, it must calculate the energy absorbed by the OPGW, I^2t, integrating the effect of the short circuit current during the fault clearing time.
The current fault and the fault clearing time may be modified by the following factors:

- The short circuit power
- The damping of the fault current until the time of clearance
- The location of the fault on the line
- The clearing time of the fault
- The fault resistance
- Grounding of EETTs
- Grounding of towers
- The impedances of the companion ground wire

Several hypotheses were performed with these factors, which serve as a framework for our study,
Regarding of short circuit power of design of EETT linked with the 500 kV system the adopted value was 25 GVA. In consequence maximum energy absorbed of OPGW cable will be associated with that design value.

The damping of the fault current to ground is produced between the sub transient period and the steady state condition.
The damping during the sub transient period is determined by the moment when the fault happen on the voltage waveform, while the damping during the transient period is determined by the machine electrically close to the point of failure and contributes to the fault current during the transient period
Given the difficulties surrounding the determining the electrical proximity of each machine is possible to adopt the hypothesis of non existence of nearby generation. Thus, it is considered a time constant of 45 ms for the damping of the DC component of the fault current during the sub transient period, and is not considered any damping during the transient period.

To find the maximum value of the I2t is necessary to considerer faults in both side of the line. The fault applied at the near side of the line is associated with short clearing time and maximum fault current whereas distant faults are associates with long clearing times but with very low fault current.
The fault resistance adopted is of null value. The value of the fault resistance has random character, reason for which is possible neglect the limiting effect on fault current to ground.
The grounding of towers and EETT offer a way of draining part of the fault current, reducing the total current to circulate through the parallel circuit formed by the impedance of the conventional ground wire and impedance of the OPGW.
The resistance of grounding of the towers was considered uniform with a value of 20 Ω, as required by projects documents. This situation does not significantly depart from reality, at least in the first years of operation. The resistance of grounding of the EETT adopts value of 1 Ω.
The study was performed with a conventional companion ground wire (GW), the energy absobed by OPGW could be further reduced by incorporating a new companion ground wire of the same section as the conventional type but of the Alumoweld type. This would reduce the direct current resistance of the companion ground wire decreasing in consequence the circulating current through the OPGW. This Alumoweld companion ground wire will be only necessary to install the first few miles from the transformer station.

5.2 Modelling and simulation

The benchmark case, see Figure #1, shows an equivalent generator with a rated voltage 22 kV, 500 kV overhead line of 50 km of length and a transformer D/Yg 22/500 kV with 12% of short circuit impedance. Generator, transformer and line models are of the EMTP type. This allows a detailed representation of the network considering all its imbalances, couplings and nonlinearities.
The rated power of the generator and transformer was adjusted in 5450 MVA so that a single-phase fault applied to the 500 kV bus produces a current fault of 28.9 kA, corresponding to a short-circuit power of 25 GVA.
The generator model takes into account all the dynamics of the synchronous machine, including the damping of the zero sequence fault current.
The three-phase transformer model considers the vector group of the primary and secondary windings and typical saturation curve with knee point zero area at 1.2 pu.
The line model used is of constant parameters, suitable for simulation of single-phase faults.
A length of 50 km of 500 kV overhead line was modelled using a representation span-span. As consequence of that we modelled 124-grounded towers and 125 spans of 500 kV line between two power stations 500 kV.

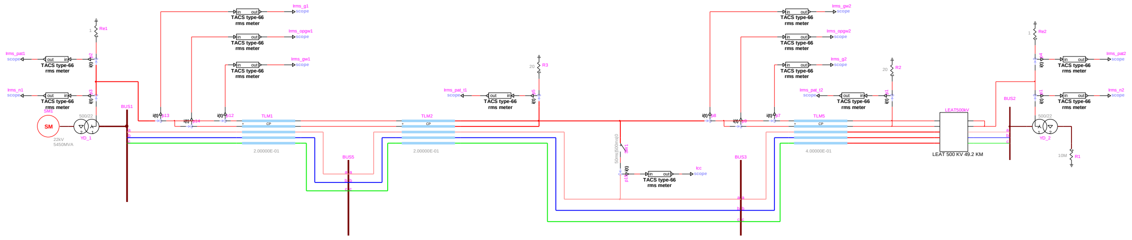

Figure #1: Fault to ground at the first tower

Energy absorbed by the OPGW cable was tested by faults near the beginning of the overhead line, simulating single phase faults at 0.4 km and 3.2 km, considering two alternatives for the companion ground wire, conventional and Alumoweld type.

The benchmark case of Figure #1 corresponds to the situation presented when to the lightning strike on one of the ground wires, after back flashover of the insulator chain remain in contact the faulted phase, the structure of the tower and its grounding.
In each simulated case are determined the total current to ground fault, the current through the parallel circuit of guard wires, the current through the ground wire companion, the current conducted by the OPGW and finally the calculated I^2t value.
The value of energy absorbed by the OPGW cable I^2t obtained by simulation is compared with the provided by the manufacturer of OPGW cable; the OPGW cable is accepted if the simulated value is below to the manufacturer's indicated limit.

The results of the simulations are summarized in Tables 1 and 2. Only the case with the highest energy absorbed was illustrated in Figure #2 and Figure # 3. The values of current and I^2t shown on the tables match with the registered at the end of the simulation.
The Table 1 shows the results with fault to ground in two different places , with conventional companion ground wire while in the
Table *2* with Alumoweld companion ground wire.

Table 1: Fault to ground and conventional companion ground wire

Distancia (km)	Tiempo de falla (s)	Icc (kArms)	Ig (kArms)	Igw (kArms)	Iopgw (kArms)	I^2t (kA^2s)
0.4	0.25	21.939 (1)	20.286 (1)	4.926 (1)	16.482 (1)	77.0 (2)
3.2	0.25	19.721	15.482	3.625	12.751	43.0

(1) Value shown in figure 2 (2) Value shown in figure 3

Table 2: Fault to ground and Alumoweld companion ground wire

Distancia (km)	Tiempo de falla (s)	Icc (kArms)	Ig (kArms)	Igw (kArms)	Iopgw (kArms)	I^2t (kA^2s)
0.4	0.25	22.013	20.450	8.283	12.810	47.0
3.2	0.25	19.995	16.077	6.471	10.165	28.0

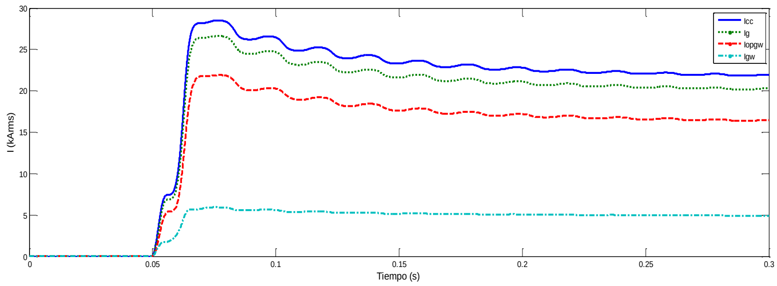

Figure #2: Fault to ground at 0.4 km and conventional companion ground wire, total current fault to ground (Icc), current trough of the parallel ground wires (Ig), current trough the OPGW (Iopgw), current trough the conventional companion ground wire (Igw)

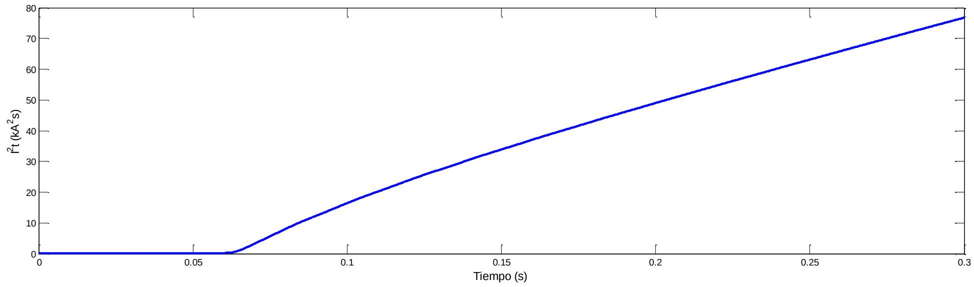

Figure #3: Fault to ground at 0.4 km and conventional companion ground wire, energy absorbed by the OPGW

6. OPTICAL CONNECTION FOR PROTECTION SYSTEMS

6.1 Aspects

One of main mission critical function is the differential protection system, that must use a permanent link between both IEDs, without interruptions and with a fixed propagation delay. The IEDs will monitor the total delay of the channel of the IEDs assuming that the way of transmission and reception will be equal, and compensating the current that will be measured in both ends. Consequently, the optical fibre of the OPGW is the best link for transmitting that digital function.

Similarly, teleprotection is another mission critical function that is necessary for transmitting the backup protection function, mainly by digital teleprotection equipment where, again, the optical fibre of the OPGW is the best link for transmitting that digital function

Synchronization, delay, time of transmission, etc (related to protection systems) will be not considered in this paper because we only describe the ways of connection of the IEDs by the optical cables (topic of the paper)

6.1 Interfaces

Differential protection systems are typically provided with fibre optic interface (IEEE C37.94) for interlinking the IEDs via a dedicated pair of fibres without intermediate communications equipment (direct link)

In general the optical interface (protection side) is native of the IED manufacturer, so it is necessary to incorporate an optical / electrical converter to allow linking: the terminal protection with the SDH multiplexer. Because of this, the manufacturer of the protective terminal can provide an open standard interface (on G.703 E1 frame) instead of the proprietary optical interface

If we use the IEEE C37.94 standard (by optical fibers from 64 kbps to 256/512 kbps) as a interface of the relay/IED of the protection system, it is possible to achieve a direct connection through the SDH communications system without converters (indirect link)

Not use wiring has the advantage to avoid electromagnetic interference, especially when the relay / IED of the protection system is housed in a remote kiosk where communications equipment are far away of the kiosk

Taking into account that the relay/IED of the protection systems is originally provided with optical interface, it is necessary that the network management system of the protection system includes the information of the converter, in order to have the full information and parameters of the IED (converter included)

6.2 Linkage modes

6.2.1 Direct protection link (DW #4)

The differential protection IEDs can get maximum values of availability linking using the following options:

a) for ANSI-87L/87T function (differential protection; main system), it is recommended to use an optical terminal suitable separate output for fibers SM operating in the third optical window (1550 nm) with dedicated fibers (fo # 1; fo # 2).
   The information needed for calculating the differential current is exchanged in full duplex mode using synchronous serial digital frame at speeds from 64 kbps to 256/512 kbps
   If the 87L / 87T function used is sufficient to connect the current transformer CT of the substation
b) for the ANSI-21/21N function (distance protection, back up system), it is recommended to use another independent optical output terminal, suitable for dedicated SM fibers operating in third optical window (1550 nm) with other dedicated fibers (fo # 3; fo # 4)
c) Also, for the ANSI-21/21N function (distance protection, backup system), it is possible to use the communication link through independent optical SM fibres (fo #3¸fo #4)
   When using both functions (87L/87T and 21/21N) is required to connect the current transformer CT and VT voltage transformer of the substation

6.2.2 Indirect link through the Communication link (DW #5)

A lower availability of linkage is obtained by the following options:

a) for ANSI-87L/87T function (differential protection; main system), it is possible to use a G.703 interface through the SDH multiplexer. The information needed for calculating the differential current are exchanged in a full duplex mode with a frame digital synchronous serial speed of 64 kbps (or similar).
b) for the ANSI-21/21N function (distance protection; back up system), the independent orders are sent by a digital teleprotection terminal. It is connected through the multiplexer by a interface G.703 (E1 speed)

6.2.3 Backup protection function embedded in the main frame (DW #6)

When used ANSI-87L/87T function (differential protection; main system) and also the ANSI-21/21N function (back up system) that is embedded within the frame, it is not used a separate output for the impedance protection function. In this case the link may be implemented through dedicated fiber optic or digital multiplexer communications system (by sending both protection functions together).

7 ASSURING CABLE QUALITY

In order to assure the quality of the optical cable, it is necessary to pay attention about some topics, as follows:

a) Type tests: according to the procedures of international standards; doing the tests in independent and prestige laboratory; in a recent date; executed on an equal cable (not on a similar one)
b) Routing tests: along the manufacturing process and according to the QA plan of the manufacturer
c) Verifying the traceability of the materials involved in the manufacturing process of the cable
d) Factory acceptance tests: to be done on the whole optical cable, as well as to each of its components
e) Tests to performance of the OPGW cable: galloping; attenuation; coefficient of PMD; chromatic dispersion; variation of attenuation versus tensile; variation of attenuation versus climatic variation (specially for temperatures below zero); slip of cable; etc
f) Tests about the disposal of mounting and installation: efficiency of damping (stockbridge action); variation of attenuation due to micro curvatures of fibres; etc
g) Verifications along the installation process: maximum tensile that is permitted; automatic control of the tensile strength; maximum radius of curvature (cable and fibers) that is permitted; maximum tensile strength up to get the maximum sag of the HV Line; on-line measurements of the parameters as well as continuous registration of the values
h) Measurements along the installation process: partial measurements of the characteristics of the fibers, splices, etc
i) Commissioning tests: measurements of the parameters of each fiber after the installation and splicing process.
j) Characterization of the optical cable after installation and its fibers in the final end-to-end configuration (attenuation; PMD; chromatic dispersion; etc)

8 MAIN DESIGN ASPECTS

For the design and project of the OPGW it is necessary to take into account as well as to analyze carefully the following aspects:

a) General aspects: cable useful life not less than 25 years; tensile strength; sensitivity to macro and micro bends; thermal stability
b) Mechanical aspects: structures of the HV Line; spans of the Line; maximum sag
c) Electrical aspects: high voltage level; short circuit current; atmospheric discharges
d) Environmental: maximum wind; range of temperature; ice; corrosion; etc
e) Optical aspects: attenuation; PMD coefficient; chromatic dispersion; etc
f) Calculations of sag of the OPGW under adverse climatic conditions; calculation of deflection under wind action; galloping due to ice detachment and/or wind action; mechanical interference/interaction between the deflexion of the OPGW cable and deflexion of the phase conductors

9 OPTICAL FIBERS

It is preferable the use of optical fibers single mode (SM-9/125-LWPF) according to UIT-T G.652D (zero water peak-SM/ZPW), in order to allow the use the whole wavelength spectrum (Lambda) due to the removal of hydroxyls (HO-) included into the conventional fibers (lambda:1383 +/- 3 nm). It permits to get a wide wavelength spectrum between 1260 and 1625 nm (increasing the usable spectrum in the order of 65%). It permits a greater own use, as well as to rent fibers with no restriction to the Data Carriers due to the greater benefits than the conventional fibers.

Even more, it is desirable to use optical fibers according UIT-T G.657 A 1/A2 with low sensitivity to bending, which assure:

- better performance of the OPGW during the installation process of the cable
- reduction of extrinsic effects along the cable useful life period (effect of galloping; eventual displacement of the dumpers; etc)
- reduction of risks during the fibres splicing procedures

The fibers according to G657A1/A2 are compatible with G.652D from the point of view of the parameters as attenuation of fibres, PMD coefficient, chromatic dispersion; it is possible to use the full of bands O, E, S, C, L (according G.694.1 y G.957) with insensitivity against bends; use of the wide wavelength in the range of 1260-1625nm for full use of techniques of CWDM and DWDM

10 OPERATION AND MAINTENANCE

a) The failure of a conventional Ground Wire (galvanized wire) will be evidenced when it is produced a cut and fall out of the HV Line structure. It configures a critical failure.
Meanwhile the failure in a OPGW will begin to be evidenced due to previous factors as:

- Increasing the losses of the optical fibers
- Deformation/stretching of the optical fibers
- Moisture penetration in the optical cable and/or in the splicing boxes

It means that exists a substantial advantage due to the early diagnosis of a eventual failure, through the on line monitoring of performance of the bit error rate (BER) of the Communication System (Network Management System-NMS), as well as through a monitoring of the optical cables and/or monitoring of its optical fibers. It can be done automatically in real time or through periodical measurements of the fibers by maintenance people (manually)

b) The failures in the optical fibers will be produced mainly by:

- Excessive tensile strength
- Bending radius exceeded (of the whole cable or its fibers)
- Torsion of the optical cable during the installation process
- Defectives splicing boxes (humidity)
- Execution the splicing of fibers in a defective manner, with dust and/or grease on surfaces, causing micro curvatures, etc
- Excessive vertical pressure on the cable

c) A reliable maintenance process must include the following stages:

- Permanent supervision through the communication system (BER measurement) in order to have an early detection of performance degradation of the fibers and the optical cable
- Continuous measurement of the optical cable and/or its fibers in order to confirm (or not) if the parameters are into the originals right values relieved during the commissioning stage
- In case of failure situation:
  - *to switch to other fibers (into the same OPGW), in case of failure of a particular fiber
  - *to switch to the backup communication system #2 (failure of the optical cable)
- Restoration to the normal operation after any repair task, with a new full characterization of fibers
- Analysis of the failure in order to do preventive actions, as well as to minimize future corrective tasks

11. NETWORK MANAGEMENT SYSTEMS (NMS)

It is highly recommended provide a monitoring system for the whole equipment involved, as well as for the optical cable, in order to increase the Availability of the High Voltage Transmission System.
It is recommended the provision of:
*a NMS for the communication system (and eventual amp devices)
*a NMS for the differential protection system
*a NMS for the teleprotection system
*a NMS for monitoring the optical cable (and/or its optical fibers)
In all cases, the network management systems will allow to do the reconfiguration of devices, monitoring the main parameters of equipment, checking the functioning of each part and the normal settings, etc. Using these tools, as it was mentioned at the beginning of the paper, high Ai figures will be obtained as well as the OPex will be minimized

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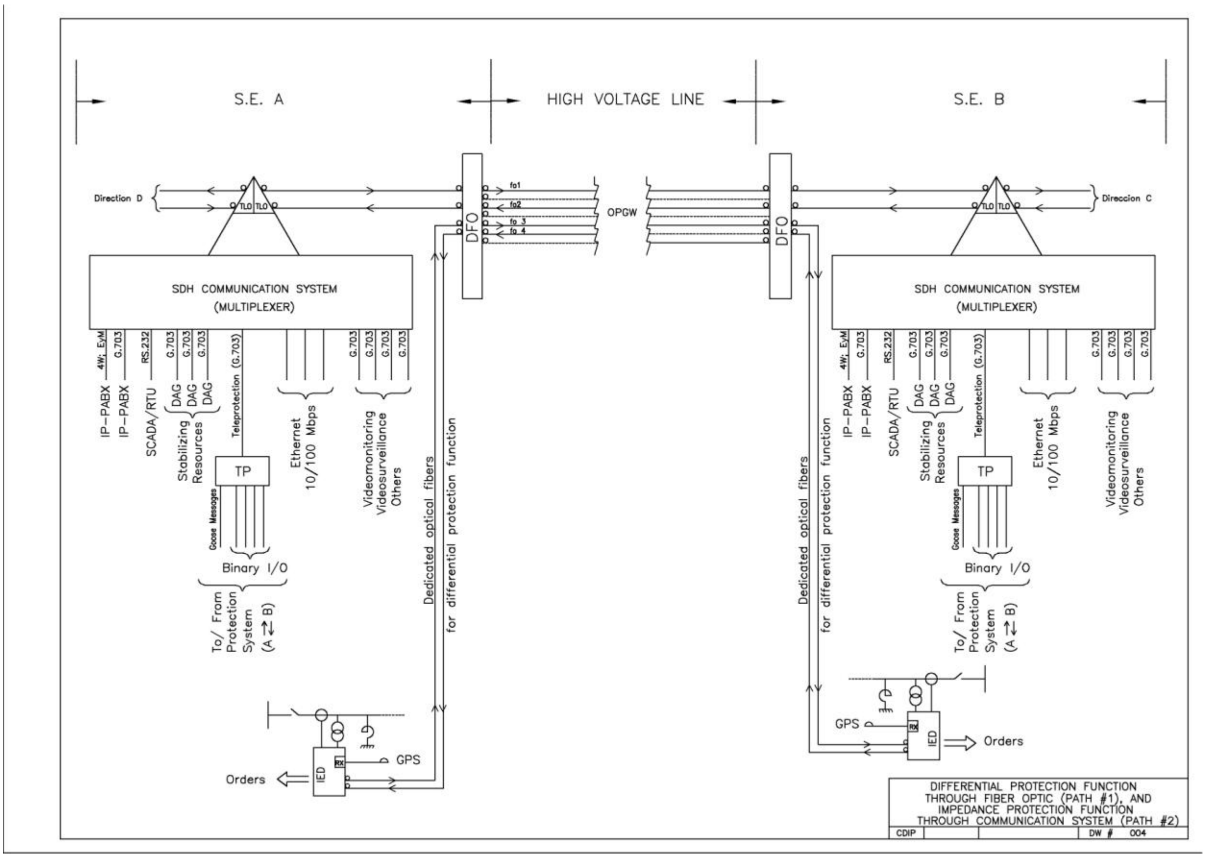
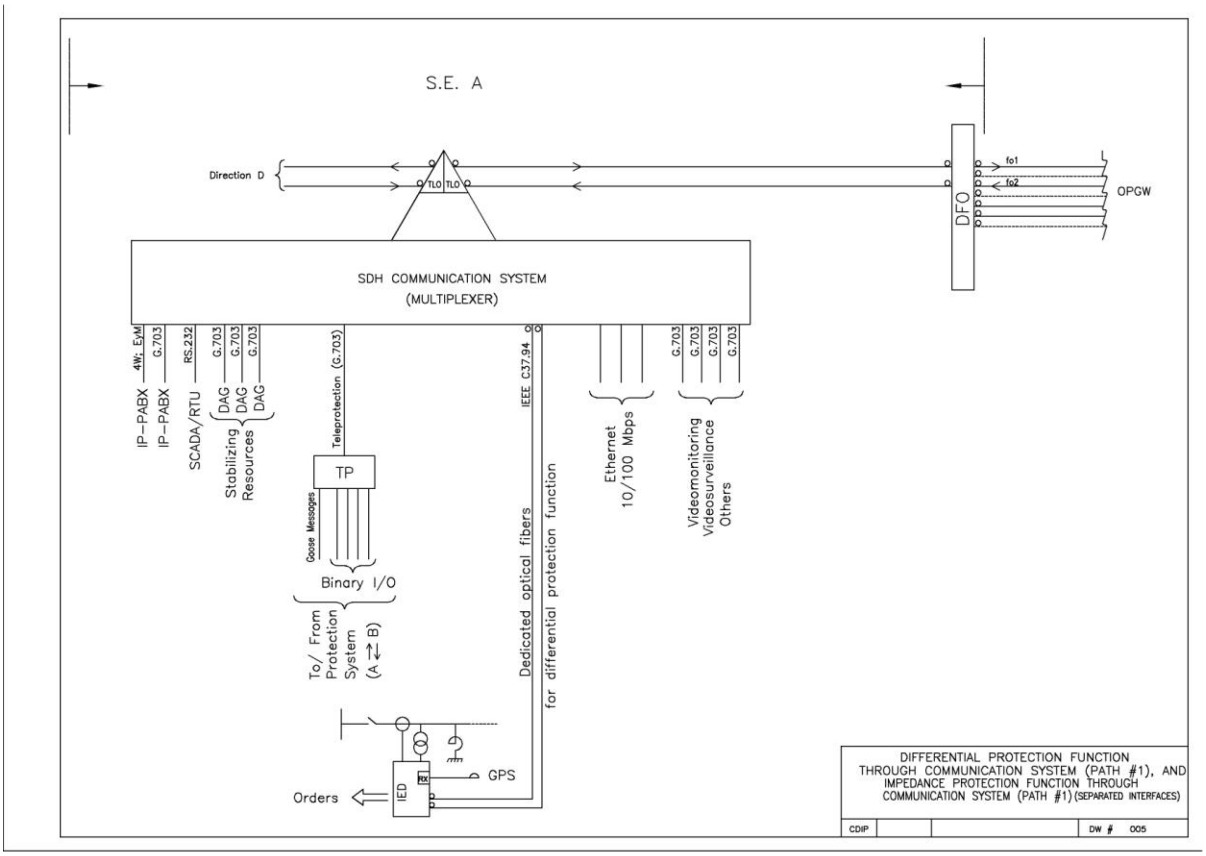

S.E. A
HIGH VOLTAGE LINE
S.E. B
OPGW
SDH COMMUNICATION SYSTEM
(MULTIPLEXER)
DFO
Direction D
Direccion C
TP
Binary I/O
To/ From Protection System (A ⇄ B)
Ethernet 10/100 Mbps
Videomonitoring Videosurveillance Others
Dedicated optical fibers for differential protection function
IP–PABX
SCADA/RTU
Stabilizing Resources
Teleprotection (G.703)
GPS
IED
Orders
DIFFERENTIAL PROTECTION FUNCTION THROUGH FIBER OPTIC (PATH #1), AND IMPEDANCE PROTECTION FUNCTION THROUGH COMMUNICATION SYSTEM (PATH #2)
CDIP
DW # 004


S.E. A
Direction D
OPGW
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SDH COMMUNICATION SYSTEM
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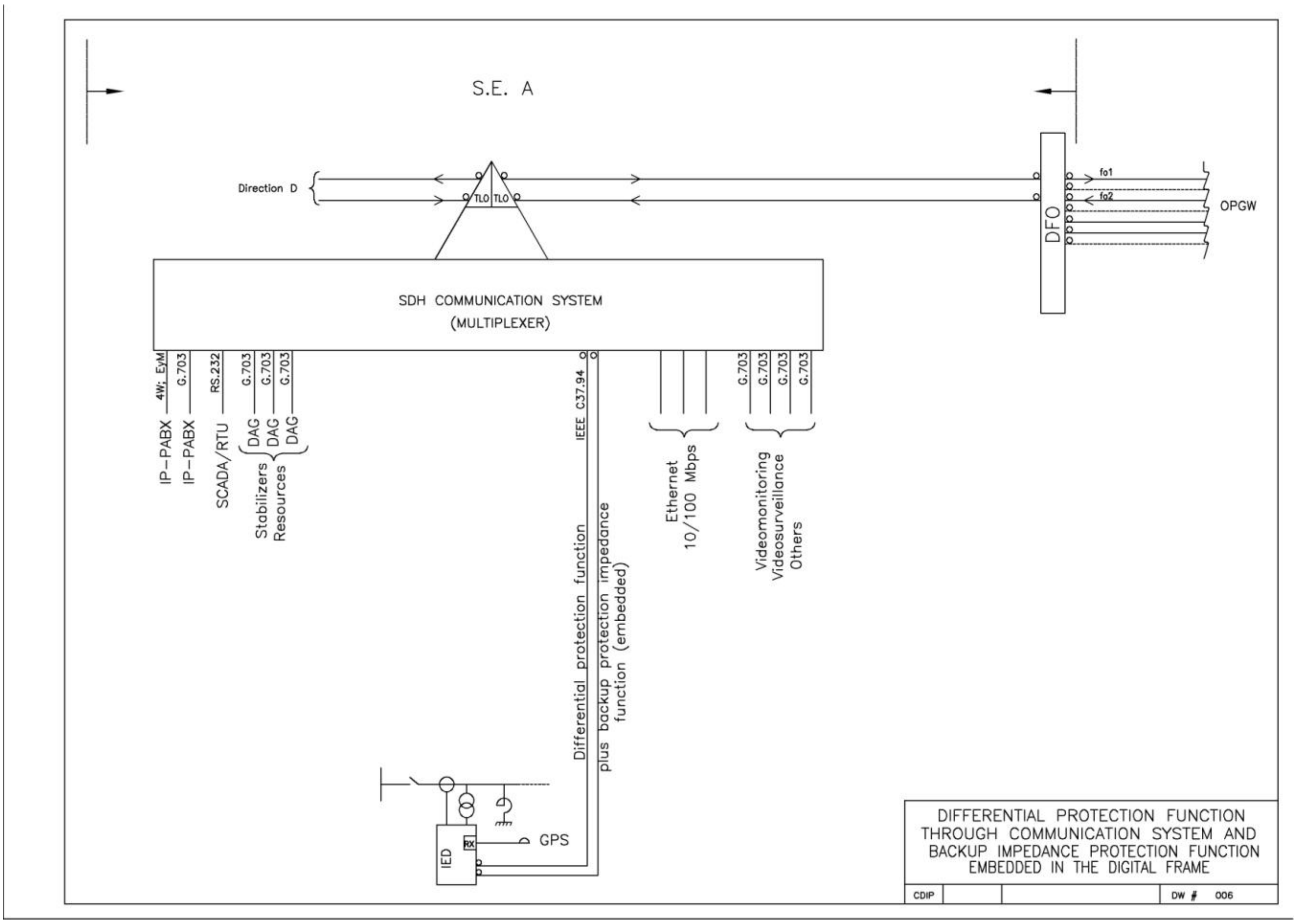
IP–PABX
IP–PABX
SCADA/RTU
Stabilizing Resources
Teleprotection (G.703)
IEEE C37.94
TP
Goose Messages
Binary I/O
To/ From Protection System (A ⇄ B)
Dedicated optical fibers for differential protection function
Ethernet 10/100 Mbps
Videomonitoring Videosurveillance Others
GPS
IED
Orders
DIFFERENTIAL PROTECTION FUNCTION THROUGH COMMUNICATION SYSTEM (PATH #1), AND IMPEDANCE PROTECTION FUNCTION THROUGH COMMUNICATION SYSTEM (PATH #1) (SEPARATED INTERFACES)
CDIP
DW # 005


S.E. A
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TLO
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fo2
OPGW
SDH COMMUNICATION SYSTEM
(MULTIPLEXER)
4W; EyM
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RS.232
G.703
G.703
G.703
IP-PABX
IP-PABX
SCADA/RTU
DAG
DAG
DAG
Stabilizers
Resources
IEEE C37.94
Differential protection function
plus backup protection impedance
function (embedded)
Ethernet
10/100 Mbps
G.703
G.703
G.703
G.703
Videomonitoring
Videosurveillance
Others
IED
RX
GPS
DIFFERENTIAL PROTECTION FUNCTION
THROUGH COMMUNICATION SYSTEM AND
BACKUP IMPEDANCE PROTECTION FUNCTION
EMBEDDED IN THE DIGITAL FRAME
CDIP
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