International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.664
(10/2012)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Transmission media and optical systems characteristics – Characteristics of optical components and subsystems

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Optical safety procedures and requirements for optical transmission systems

Recommendation ITU-T G.664

ITU-T

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Recommendation ITU-T G.664

Optical safety procedures and requirements for optical transmission systems

Summary

Recommendation ITU-T G.664 provides guidelines and requirements for techniques to enable optically safe working conditions (for the human eye and skin) on optical interfaces of the optical transport network, in particular, for systems employing high-power Raman amplification techniques, for equipment in restricted and controlled locations.

Due to revisions of relevant IEC requirements, the automatic laser shut-down (ALS) procedure, defined in a previous version of this Recommendation for synchronous digital hierarchy (SDH) systems, is no longer necessary and has therefore been moved to an informative appendix. Furthermore, this Recommendation provides new guidelines on automatic power reduction (APR) procedures for systems employing high-power Raman amplification techniques and this latest version includes Raman-based GPON reach extension systems.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.664	1999-07-02	15
2.0	ITU-T G.664	2003-03-16	15
2.1	ITU-T G.664 (2003) Amd. 1	2005-01-13	15
3.0	ITU-T G.664	2006-03-29	15
4.0	ITU-T G.664	2012-02-13	15
5.0	ITU-T G.664	2012-10-29	15

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Optical safety procedures and requirements for optical transmission systems

1 Scope

This Recommendation provides guidelines and requirements for techniques to enable optically safe working conditions (for the human eye and skin) on optical interfaces of optical networks, for both access and transport applications, including conventional synchronous digital hierarchy (SDH) systems, for equipment in both restricted and controlled locations.

The actual definition and specification of optically safe levels are considered outside the scope of this Recommendation (they are provided by IEC).

The main fields of application are systems designed for the optical networks, both in access and transport applications, employing Raman amplification and dense wavelength division multiplexing (DWDM) systems with large channel counts. For the purpose of ease of operating these systems, this Recommendation focuses on automatic power reduction (APR) techniques with automatic restart.

As backwards compatibility with earlier Recommendations on the subject of optical safety is desired, this Recommendation provides some descriptions for safety procedures in the case of single and multichannel SDH systems with and without line amplifiers. Clarification is given as to why procedures employing restart pulses for automatic laser shut-down (ALS) and automatic power shut-down (APSD), defined in a previous version of this Recommendation, are no longer appropriate or necessary for applications given in [ITU-T G.691], [ITU-T G.693], [ITU-T G.695], [ITU-T G.957] and [ITU-T G.959.1].

The impact of bidirectional transmission as described in [ITU-T G.692] has also been considered.

Some references are provided for keeping fibres damage-free when being operated at high optical power levels.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.662] Recommendation ITU-T G.662 (2005), *Generic characteristics of optical amplifier devices and subsystems*.

[ITU-T G.665] Recommendation ITU-T G.665 (2005), *Generic characteristics of Raman amplifiers and Raman amplified subsystems*.

[ITU-T G.691] Recommendation ITU-T G.691 (2006), *Optical interfaces for single channel STM-64 and other SDH systems with optical amplifiers*.

[ITU-T G.692] Recommendation ITU-T G.692 (1998), *Optical interfaces for multichannel systems with optical amplifiers*.

[ITU-T G.693] Recommendation ITU-T G.693 (2009), *Optical interfaces for intra-office systems*.

[ITU-T G.695] Recommendation ITU-T G.695 (2010), *Optical interfaces for coarse wavelength division multiplexing applications*.

[ITU-T G.698.1] Recommendation ITU-T G.698.1 (2009), *Multichannel DWDM applications with single channel optical interfaces*.

[ITU-T G.698.2] Recommendation ITU-T G.698.2 (2009), *Amplified multichannel dense wavelength division multiplexing applications with single channel optical interfaces*.

[ITU-T G.783] Recommendation ITU-T G.783 (2006), *Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks*.

[ITU-T G.798] Recommendation ITU-T G.798 (2010), *Characteristics of optical transport network hierarchy equipment functional blocks.*

[ITU-T G.872] Recommendation ITU-T G.872 (2001), *Architecture of optical transport networks*.

[ITU-T G.957] Recommendation ITU-T G.957 (2006), *Optical interfaces for equipments and systems relating to the synchronous digital hierarchy*.

[ITU-T G.959.1] Recommendation ITU-T G.959.1 (2009), *Optical transport network physical layer interfaces*.

[ITU-T G.983.x] Recommendation ITU-T G.983.x series, *Broadband optical access systems based on Passive Optical Networks (PON).*

[ITU-T G.984.x] Recommendation ITU-T G.984.x series, *Gigabit-capable passive optical networks (GPON).*

[ITU-T G.984.6] Recommendation ITU-T G.984.6 (2008), *Gigabit-capable passive optical networks (GPON): Reach extension*.

[ITU-T G.985] Recommendation ITU-T G.985 (2003), *100 Mbit/s point-to-point Ethernet based optical access system*.

[ITU-T G.986] Recommendation ITU-T G.986 (2010), *1 Gbit/s point-to-point Ethernet-based optical access system*.

[ITU-T G.987.x] Recommendation ITU-T G.987.x series, *10-Gigabit-capable passive optical network (XG-PON) systems*.

[IEC 60825-1] IEC 60825-1 edition 2.0 (2007), *Safety of laser products – Part 1: Equipment classification and requirements*.

[IEC 60825-2] IEC 60825-2 edition 3.2 (2010), *Safety of laser products – Part 2: Safety of optical fibre communication systems (OFCS).*

[IEC/TR 61292-4] IEC/TR 61292-4 edition 2.0 (2010), *Optical amplifiers – Part 4: Maximum permissible optical power for the damage-free and safe use of optical amplifiers, including Raman amplifiers*.

3 Terms and definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 controlled locations: [IEC 60825-2].

3.1.2 hazard level: [IEC 60825-2].

3.1.3 laser class: [IEC 60825-1].

3.1.4 Loss of Signal (LOS): [ITU-T G.783].

3.1.5 LOS overhead (LOS-O): [ITU-T G.798].

3.1.6 LOS payload (LOS-P): [ITU-T G.798].

3.1.7 optical multiplex section (OMS): [ITU-T G.872].

3.1.8 optical supervisory channel (OSC): [ITU-T G.692].

3.1.9 optical transmission section (OTS): [ITU-T G.872].

3.1.10 restricted locations: [IEC 60825-2].

3.1.11 unrestricted locations: [IEC 60825-2].

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 automatic laser shut-down (ALS): A technique (procedure) to automatically shut down the output power of laser transmitters and optical amplifiers to avoid exposure to hazardous levels.

3.2.2 automatic power reduction (APR): A technique (procedure) to automatically reduce the output power of optical amplifiers to avoid exposure to hazardous levels.

3.2.3 automatic power shut-down (APSD): A technique (procedure) to automatically shut down the output power of optical amplifiers to avoid exposure to hazardous levels; within the context of this Recommendation, the term APSD is equivalent to the term ALS.

3.2.4 loss of continuity (of an optical link): Any event which may cause hazardous optical power levels to be emitted from some point along the path of an optical transmission system. Common causes of loss of continuity of an optical link are a cable break, equipment failure, connector unplugging, etc.

3.2.5 main (optical) path: The fibre plant between the source main path interface reference point (MPI-S), S or S' point of the transmitting equipment and the receive main path interface reference point (MPI-R), R or R' point of the receiving equipment.

3.2.6 main path interfaces: The interfaces to the fibre plant.

3.2.7 optical auxiliary channel (OAC): An optical signal that fails in the event of loss of fibre continuity but does not require hazardous power levels to operate satisfactorily. One implementation of an OAC is the use of an optical supervisory channel (OSC).

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

AEL	Accessible Emission Limit
ALS	Automatic Laser Shut-down
APR	Automatic Power Reduction
APSD	Automatic Power Shut-down
ASE	Amplified Spontaneous Emission
BA	Booster Amplifier
DEMUX	Demultiplexer
dLOS	Loss Of Signal defect

DS Downstream

DWDM Dense Wavelength Division Multiplexing

IaDI Intra-Domain Interface

LA Line Amplifier

LOS Loss Of Signal

LOS-O LOS Overhead

LOS-P LOS Payload

MPE Maximum Permissible Exposure

MPI Main Path Interface

MPI-R Receive Main Path Interface reference point

MPI-S Source Main Path Interface reference point

MSP Multiplex Section Protection

MUX Multiplexer

OA Optical Amplifier

OAC Optical Auxiliary Channel

OAN Optical Access Network

OAR Optically Amplified Receiver

OAT Optically Amplified Transmitter

OMS Optical Multiplex Section

ONU Optical Network Unit

OSC Optical Supervisory Channel

OTN Optical Transport Network

OTS Optical Transmission Section

PA Preamplifier

RE Reach Extender

SDH Synchronous Digital Hierarchy

US Upstream

WDM Wavelength Division Multiplexing

5 General considerations

5.1 Safety considerations for avoiding damage to the human eye and skin

[IEC 60825-2] provides a clarification of the difference between laser class and hazard level. The text below is taken from [IEC 60825-2][1].

"**Class**: The word "Class" refers to a scheme by which, based on emission levels, a product or internal emitter can be grouped with respect to its safety. These levels are described in the Accessible Emission Limit Tables in [IEC 60825-1]. Classes range from Class 1, which is safe

[1] IEC 60825-2 ed.3.2 Copyright © 2010 IEC Geneva, Switzerland. www.iec.ch.

under reasonably foreseeable conditions, to Class 4, which is potentially the most hazardous case. In [IEC 60825-1], the classification of products is based on reasonably foreseeable operating conditions including single fault conditions."

"**Hazard Level**: "Hazard Level" is a term used in this standard which refers to the potential hazard from laser emissions at any location in an end-to-end fibre optic communication system that may be accessible during use or maintenance or in the event of a failure or fibre disconnection. The assessment of the hazard level uses the Class Accessible Emission Limit tables described in the [IEC 60825-1]."

"A whole optical fibre communication system will not be classified in the same way as required by [IEC 60825-1]. This is because, under intended operation, the optical radiation is totally enclosed, and it can be argued that a rigorous interpretation of [IEC 60825-1] would give a Class 1 allocation to all systems, which may not reflect the potential hazard accurately."

"Based upon this statement, a complete optical fibre communications system can be regarded as a Class 1 laser product because, under normal conditions, the emissions are completely enclosed (like a laser printer) and no light should be emitting outside the protective housing. It is not until the fibre becomes broken or an optical connector is unplugged, that someone might be exposed to a level of optical radiation which is potentially hazardous (if the internal emitters or amplifiers are of high enough power)."

"Therefore, for each optical output port the Hazard Level must be assessed. The Hazard Level limits are dependent on the "dominant" wavelength range, taking into consideration that [IEC 60825-1] defines different limits for different wavelength ranges. Details can be found in [IEC 60825-1]. Furthermore, this standard allows the use of automatic power reduction (APR) techniques to achieve a lower (less hazardous) Hazard Level based on the normal power in the fibre and speed of automatic power reduction."

In this Recommendation, automatic laser shut-down (ALS) techniques (in the case of SDH systems), which were originally designed for the same purpose, i.e., to provide safe working environments, are also described in Appendix II.

NOTE 1 – Over the past years the term automatic power shut-down (APSD) has also been used for systems with optical amplifiers. Because the term ALS has been in use much longer, in this Recommendation the term ALS will be used, noting that in this context the term APSD is intended to be equivalent to the term ALS.

Actual details about the various class and hazard level limits are provided by [IEC 60825-1] and [60825-2] respectively. A further clarification on actual levels and power reduction times for the various safety categories is provided by [IEC/TR 61292-4].

It should furthermore be noted that, for the hazard level assessment, only those power levels should be considered which might occur under reasonably foreseeable conditions. [IEC 60825-2] provides some description and guidance to define the meaning of "reasonably foreseeable".

For the purposes of this Recommendation, it is assumed that optical transport network (OTN) equipment in general (including SDH equipment) will only be deployed in controlled and restricted locations. In [IEC 60825-2], it is defined that the hazard level of equipment shall not exceed 1M in restricted locations and 3B in controlled locations. Additional requirements for controlled locations, which are outside the scope of this Recommendation, can be found in [IEC 60825-2].

In a similar way as for OTN equipment, [IEC 60825-2] defines that the Hazard level for access equipment shall not exceed 1M in restricted locations and 3B in controlled locations. Within this context it should be noted that, according to [IEC 60825-2] in the parts of access systems which are deployed in unrestricted locations (e.g., at optical network unit (ONU) locations), the Hazard level shall not exceed 1.

NOTE 2 – In previous versions of [IEC 60825-1] and [IEC 60825-2], a Class 3A and Hazard level 3A were used respectively. In many systems deployed in the field, a Hazard level 3A might have been used. In the latest [IEC 60825-1] and [IEC 60825-2], this 3A category has been replaced by a new category 1M. In particular, in the 1550 nm window, the 3A exposure limit was a fixed limit, in contrast to the 1M level, which is expressed by a formula and, as such, determined by several factors specified by [IEC 60825-1] (e.g., exposure time, wavelength, fibre mode field diameter, measurement diameter and measurement distance). For the applications covered by this Recommendation, the Hazard level 1M limit is generally higher than the previous Hazard level 3A limit due to divergence of the beam from the optical fibre into free space. In this Recommendation, general reference is made to the new Hazard level 1M instead of the previous Hazard level 3A. In situations where the hazard level assessment is still 3A, it is suggested to use the guidelines applicable to Hazard level 1M.

In systems which have an operational power in the fibre exceeding the potentially hazardous levels 1M or 3B in the case of restricted or controlled locations respectively, an APR or ALS capability shall be used to reliably reduce the operational power to a level below the safety level applicable for the type of location. More detailed requirements are defined in clause 6. General requirements for disabling the APR, including specific requirements for systems with operational power levels 3B or 4, are provided by [IEC 60825-2].

Furthermore, [IEC 60825-2] provides guidelines on the reliability of APR procedures.

5.2 Considerations to keep fibres damage-free

When optical fibres are being operated at high optical power levels, fibres and optical connectors could be damaged under certain conditions. Some aspects of this high power operation in fibres and connectors are also indirectly related to safety. For example, fires may be started by local heating in contaminated connectors carrying high optical power.

[IEC/TR 61292-4] provides extensive guidance on the following topics:

– fibre fuse and its propagation

– loss-induced heating at connectors or splices

– connector end-face damage induced by dust/contamination

– fibre-coat burn/melt induced by tight fibre bending.

Furthermore, [b-ITU-T G-Sup.39] contains information on the following topics:

– best practices for optical power safety.

In particular the propagation of fibre fuse might create fire hazards. While the use of automatic power reduction techniques described in this Recommendation could limit the propagation of fibre fuse, it is not regarded as one of the primary objectives of these power reduction techniques.

6 Procedures and guidelines

6.1 General

For eye safety considerations, according to [IEC 60825-1] and [IEC 60825-2], it may be necessary to provide for a capability for automatic (optical) power reduction (APR) in the case of loss of optical power within one section of the main optical path. For example, this loss of power can be caused by cable break, equipment failure, connector unplugging, etc. This condition can be generically referred to as a loss of continuity within a fibre link. To facilitate an easy restoration of the system after reconnection of the link, it is recommended to use APR procedures with automatic restart and, further, it is not recommended to use APR procedures that require a manual restart.

In clauses 6.2 and 6.3, basic requirements and guidelines are given for automatic power reduction (APR) and restart procedures for systems where power levels above Hazard level 1M in restricted and 3B in controlled locations are unavoidable (including OTN applications).

NOTE 1 – A disabling of the restart mechanism might be desirable, for example to repair a broken fibre without being disturbed by premature restart attempts.

NOTE 2 – While [IEC 60825-2] permits the usage of systems with Hazard level 3B in controlled locations, it should be noted that a system which is restricted to Hazard level 1M (either directly or via the APR mechanism) would be acceptable for use in either restricted or controlled locations and would therefore be much more widely deployable.

In a previous version of this Recommendation, regularly transmitted (restart) pulses were used to facilitate the restoration of the system. The use of pulses was a very convenient means for establishing restart in transversely compatible procedures. As clarified in Appendix II, the use of restart pulses with full operational power is, however, no longer considered appropriate because of revised IEC safety requirements. Because alternative transversely compatible APR procedures have not yet been established by ITU-T, it is recommended to specify transversely compatible interfaces with optical power levels at Hazard level 1M (or 3B in the case of controlled locations) or lower.

As clarified under clause 5, it is not necessary to provide a power reduction procedure for systems of Hazard levels 1 and 1M according to [IEC 60825-2]. This is, furthermore, not necessary for systems with Hazard level 3B in controlled locations. Currently, all optical power levels specified in [ITU-T G.691], [ITU-T G.693], [ITU-T G.695], [ITU-T G.957] and [ITU-T G.959.1] are Hazard level 1M or lower. In particular, the levels in [ITU-T G.693] and [ITU-T G.957] are of Hazard level 1, thus, considered completely safe. During the discussions on the first version of [ITU-T G.957], APR was regarded necessary to maintain sufficient optical safety. Consequently, a shut-down procedure (called ALS) was defined. Because this procedure (which is no longer regarded necessary for the applications mentioned above) has been widely deployed over the past years, for example in SDH terminal equipment, it has been captured in Appendix II for historical purposes.

For optical transmission systems intended for use in the access network – [ITU-T G.985], [ITU-T G.986], [ITU-T G.983.x], [ITU-T G.984.x] and [ITU-T G.987.x] all operate at optical power levels so that APR is not required, with the exception of the Raman-based reach extender described in Amendment 2 to [ITU-T G.984.6].

6.2 APR procedures for systems employing discrete optical amplification

In this clause, basic requirements and guidelines are given for automatic power reduction (APR) and restart procedures for systems, based upon discrete optical amplification, where power levels above Hazard level 1M in restricted and 3B in controlled locations are unavoidable (including OTN applications).

In common with the other cases described in this Recommendation, APR techniques are necessary in the case that the sum of operational power (main optical signal) and pump-laser output power of the optical interfaces exceeds the applicable hazard levels defined in [IEC 60825-2]. The total power is the sum of the power in any one direction from all optical channels, the power from all pump-lasers and the power from optical auxiliary channels (OAC), if used. Within the context of this Recommendation, an optical supervisory channel (OSC) is regarded as a specific implementation of an OAC.

In 6.1, it is recommended to only use APR procedures that enable automatic restart. At the time of publication of this Recommendation, the only APR methodologies identified to be capable of providing an automatic restart were those based upon the usage of an OAC. Therefore, it is recommended to use APR procedures employing an OAC to achieve automatic restart. Specific implementation examples are provided in Appendix I. At the time of publication of this Recommendation, a transversely compatible OAC was not yet defined and therefore the specification of an APR procedure with automatic restart, suitable to support operation on transversely compatible optical interfaces, is for further study.

The time within which the power reduction has to be achieved depends on the actual operational power level. In other words, the higher the power level, the shorter the shut-down time. Requirements for shut-down times can be calculated from [IEC 60825-1] and [IEC 60825-2].

After power reduction, the remaining total power level, i.e., the sum of the power from all optical channels, the remaining power from pump-lasers and the power from an OAC, must be within Hazard level 1M (or 3B in controlled locations), noting that reduction of the total power to within Hazard level 1 or even complete shut-down is not excluded.

A generic APR description for OTN applications is shown in Figure 1. For systems employing an OAC, some implementation examples for APR procedures are given in Appendix I.

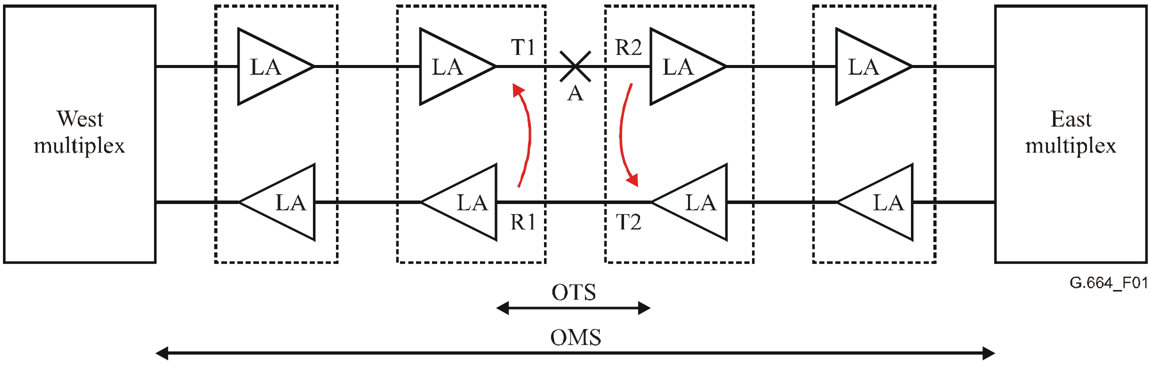


Figure 1 – Description of APR capability in the case of loss of continuity of a cable

In the case that a loss of continuity happens at point A of Figure 1, the available LOS defect indicator at receiving interface R2 is used to reduce the output power of the transmitting interface T2 which is the adjacent source in the opposite direction. This is detected in the receiving interface R1 which, in its turn, reduces the output power of the transmitting interface T1. The principle of detecting a power reduction at R1 is for further study. In the case of OTN applications, LOS-O (LOS overhead) and LOS-P (LOS payload) could be used. Definitions of LOS-O and LOS-P are given in [ITU-T G.798].

NOTE 1 – In this generic description, the power on both the impacted link and the counter-propagating link within an OTS is reduced. In clause I.3, an example procedure is given where only the power on the impacted link is reduced.

NOTE 2 – In [ITU-T G.798], an APR control command is defined for the case of OTN applications.

The power reduction to Hazard level 1M for restricted locations (or 3B in controlled locations) on all optical outputs within the impacted OTS shall be carried out within a certain time (with a maximum of 3 s) from the moment the continuity in the OTS is interrupted. The specific shut-down time is dependent on the actual operational optical power and can be calculated from the maximum permissible exposure (MPE) specification in [IEC 60825-1]. See also [IEC 60825-2].

NOTE 3 – Secondary actions on other amplifiers in the impacted OMS section, including those potentially active on equipment (e.g., single-channel equipment) outside the OMS, are not excluded but a corresponding specification is regarded outside the scope of this Recommendation. These secondary actions shall not interfere with the safety procedures on the impacted OTS.

When the connection in the OTS has been repaired, an automatic restart is necessary to restore transmission within the OTS. After restoration of the link continuity, the power above Hazard level 1M (or 3B in controlled locations) can be restored after 100 s has elapsed from the moment the loss of continuity has occurred. A time shorter than 100 s is feasible, but the possible occurrence of multiple exposures within the 100-second period has to be taken into consideration and may result in the need for a shorter APR power reduction time.

For operational reasons, it is desirable that the above-mentioned APR procedures do not result in the generation of downstream consequential alarms. In other words, alarms should only be notified by the affected OTS.

NOTE 4 – For backwards compatibility, it is allowed to use the ALS-procedure described under clause II.3 (a modification of the ALS-procedure shown in Figure II.1 with respect to timing requirements) for already installed SDH multichannel systems with line amplifiers which have operational output powers of Hazard level 3B (in the case of restricted locations). In this case, with reference to Figure II.5, depending on the specific implementation, "Tx" can be either any SDH transmitter in combination with a suitable adaptation of the MUX/OA equipment or the MUX/OA equipment. Furthermore "Rx" can be either the corresponding SDH receiver in combination with a suitable adaptation of the OA/DEMUX equipment or the OA/DEMUX equipment.

NOTE 5 – Bidirectional systems have to meet the same optical safety requirements and will use the same principles as unidirectional systems. The precise specification of these procedures is for further study.

6.3 APR procedures for systems based upon distributed Raman amplification

6.3.1 General

Optical transmission systems employing distributed Raman amplification need specific care to ensure optically safe working conditions, because high pump powers (power levels above +30 dBm are not uncommon) may be injected into optical fibre cables. Therefore, it is recommended to use APR procedures in all systems employing distributed Raman amplification with operational power levels above Hazard level 1M (or 3B in controlled locations). In this way hazards from laser radiation to human eye or skin and potential additional hazards, such as temperature increase (or even fire) caused by locally increased absorption due to connector pollution or damage, are avoided. As stated in clause 5.2, further guidance is provided by [IEC/TR 61292-4].

Distributed Raman-based systems differ from discrete optically amplified systems due to the possible presence of pump lasers at the "receiving" side of a link, launching high optical powers backward into the link. In order to ensure that the power levels emitting from broken or open fibre connections are at safe levels, it is necessary to reduce the power not only on the main optical signal sources but also on all pump-lasers employed, including the reverse pump lasers. Because the operating wavelength of the Raman pumps is usually different from the actual data signal, separate assessments at the various wavelengths used (thus both at pump laser wavelength and at main signal wavelength) need to be made.

For the same reasons as for systems employing discrete optical amplification (described in clause 6.2), for systems employing distributed Raman amplification it is recommended to only use APR procedures that enable automatic restart. Therefore also, in this case, it is recommended to use APR procedures employing an OAC to achieve automatic restart. Specific implementation examples are provided in Appendix I for OTN applications and Appendix III for access applications. At the time of publication of this Recommendation, a transversely compatible OAC was not yet defined and therefore the specification of an APR procedure with automatic restart, suitable to support operation on transversely compatible optical interfaces, is for further study.

After power reduction, the remaining total power level, i.e., the sum of the power from all optical channels, the power from pump-lasers in the case of distributed Raman amplification and the power from an OAC, must be within Hazard level 1M (or 3B in controlled locations), noting that reduction of the total power to within Hazard level 1 or even complete shut-down is not excluded.

6.3.2 OTN applications

Also for the APR procedures described under this clause, the timing requirements as defined under clause 6.2 apply.

For OTN applications based upon distributed Raman amplification, the configuration shown in Figure 1 has to be modified because of the presence of forward and/or reverse pump power on the impacted section.

Figure 2 shows an OTN configuration with both forward and reverse pump lasers on a specific span of a (potentially multi-span) system deploying distributed Raman amplification. T1 and T2 represent the transmitting interface on this section, whereas R1 and R2 represent the receiving interface.

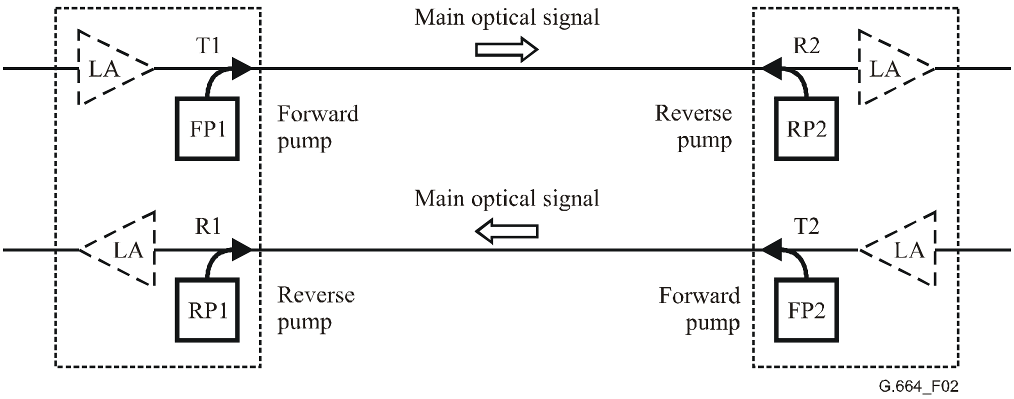


Figure 2 – Configuration with forward and reverse pump lasers in a section within a multi-span OTN system employing distributed Raman amplification

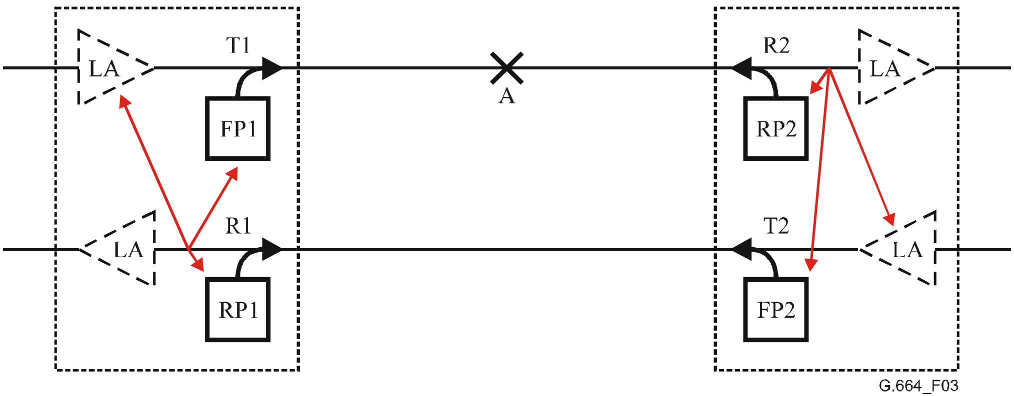


Figure 3 – Possible actions in the case of loss of continuity within a cable

If loss of continuity occurs within a fibre link, as shown in Figure 3, several actions need to be taken to ensure safe working conditions on the impacted link (in this case the upper link). Depending on the implementation of the OAC architecture, either the power on only the impacted link, or additionally, the power on the return (lower in this case) link, needs to be reduced. In either case, both the forward (pump and signal) and reverse (pump) powers have to be reduced. In the example shown in Figure 3, LOS will be detected at R2, which should be used to reduce the reverse pump power at R2 AND the forward power at T2. The forward power at T2 should be reduced sufficiently to trigger LOS at R1, which should be used to reduce the reverse pump power at R1 AND the forward power at T1.

NOTE – Care has to be taken that the possible presence of back reflected stimulated Raman amplified emission does not prevent the correct functioning of the LOS detectors.

6.3.3 OAN applications

One optical access network (OAN) application is a GPON reach extender (RE) system, as described in Amendment 2 to [ITU-T G.984.6], which uses distributed Raman amplification. Figure 4 shows an OAN configuration with pump lasers for upstream (US) and downstream (DS) signals in a PON RE system deploying distributed Raman amplification.

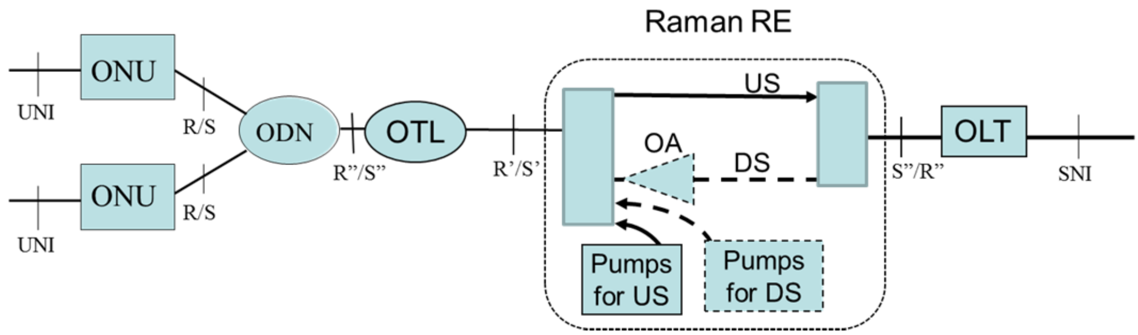


Figure 4 – Configuration with pump lasers for US and DS in a section of an OAN system employing distributed Raman amplification

As noted in clause 6.3.1 high pump powers (power levels above +30 dBm are not uncommon) may be injected into optical fibre cables depending on the actual pump power used for PON REs, potentially causing hazardous conditions when a "loss of continuity" condition occurs, as described in clause 6.1. Therefore also in this application it may be necessary to provide a capability for APR in the case of loss of optical continuity within one section of the main optical path. Also, for the APR procedures described under this clause, the general APR requirements as defined under clause 6.3.1 and the timing requirements as defined under clause 6.2 apply. Furthermore, in line with the general requirements given in clause 6.3.1, also in the case of PON REs it is recommended to use APR procedures with automatic restart.

The definition of suitable "loss of continuity" detectors within a PON RE, to be used as triggers for an APR procedure, is regarded outside the scope of this Recommendation.

Due to the multi-point nature of the ODNs within a PON and the traditional way in which PONs are operated in the field, individual ONUs may be connected/disconnected to the PON at random. Also, individual drop fibres may be disconnected by the craft or even the end user at random. These events should not trigger APR, as this might cause unwanted service outage for the remaining ONUs.

Furthermore, a Raman-pumped PON RE should be designed in such a way that the operational residual Raman pump power levels between the output ports of the final splitter and the ONUs should be within Hazard level 1 according to [IEC 60825-2] and therefore should not require APR within this part of the OAN.

An example APR system configuration is described in Appendix III.

Appendix I

Examples of automatic power reduction architectures for systems (including those based upon Raman amplification) deploying an optical auxiliary channel

(This appendix does not form an integral part of this Recommendation.)

I.1 Considerations on using an OAC instead of a restart pulse for automatic restart

The ALS procedure, defined in clause II.2, was originally defined in the 1988-1990 time-frame. An essential part of this ALS procedure is the frequent emission of a short (2 s) pulse, operating at full optical transmitter power, to restart the transmitters and consequently the receivers at both sides of the shut-down link. Under the IEC rules valid at that time, a system deploying optical interfaces compliant to [ITU-T G.957] became safe when using the above-mentioned ALS procedure.

Since then, [IEC 60825-1] and [IEC 60825-2] have undergone several modifications and also optical amplifier technology, with increasing levels of output power, has become available. In particular, systems deploying Raman amplifiers are operating at optical power levels substantially above the Hazard level 1M limit.

As clarified under clause 6.1 and in Appendix II, a restart approach using frequently emitted restart pulses with full operational power is no longer considered appropriate for a transversely compatible procedure, because of revised IEC safety requirements.

Therefore, alternative ways to perform a restart have been considered. One method is the use of an optical auxiliary channel (OAC) to verify link connectivity.

One common implementation of an OAC is an optical supervisory channel (OSC). Because an OSC is usually operating at a safe optical power level (Hazard level 1 or 1M), it can be kept "alive" on the fibre after the power has been reduced to a safe level. Restoration of OSC communication indicates full restoration of the link continuity, after which the system can be brought back to its full operational power. In this way, it is ensured that the full operational power is only present in a fully enclosed configuration guaranteeing optical safety.

NOTE 1 – The drawback of using the OSC is the fact that when it fails, automatic restart will not occur. This will, however, not impact the safety of the system.

Currently, the OSC is not required to be present on any transversely compatible link. On the other hand, an OSC is often present in IaDI system configurations, which are of proprietary nature. Therefore, in this appendix, several examples of principles of APR procedures are shown using the OSC to restart a system shut-down after loss of continuity occurs within an optical fibre link.

An alternative implementation of an OAC is the operation of the system over the impacted OTS at a reduced (safe) power level as soon as loss of continuity has occurred. By the use of a dedicated detector, specifically intended to detect low levels of optical power, link continuity can be monitored and consequently verified. As soon as link continuity has been confirmed, this dedicated detector will trigger a restart of the system. Within this context, the operation at reduced optical power can be at a constant level or pulsed as long as it remains within Hazard level 1M (or 3B for controlled locations).

NOTE 2 – Care has to be taken that the possible presence of back reflected stimulated Raman amplified emission does not prevent the correct functioning of the LOS detectors.

I.2 Description of APR procedure using co-propagating OSC

In Figure I.1 a multichannel configuration is shown, where, in the upper link besides "traffic", an OSC, called OSC-WE, is also travelling from the West multiplex to the East multiplex and, in the lower link an OSC, called OSC-EW, is travelling from the East multiplex to the West multiplex. Within the context of this example, this configuration is referred to as a co-propagating configuration.

In the case that loss of continuity occurs at point A in the OTS indicated in Figure I.1, at receiving interface R2 both LOS-P (LOS payload) and LOS-O (LOS Overhead) will occur. Then, in line with the APR procedure described in clause 6.2, the optical power at transmitting interface T2 should be reduced sufficiently to meet the appropriate hazard level. In the case that reverse pumped Raman amplifiers are used, the power inserted backwards into the upper link from receiving interface R2 should be reduced as well. At the same time, the OSC-EW should send a signal towards receiving interface R1 to indicate that, at transmitting interface T1, the optical power should be reduced accordingly. The powers at both T1 and T2 should be reduced within a certain time, depending on several parameters, such as operational power within the fibre, fibre diameter and wavelength. Details are provided by [IEC 60825-1] and [IEC 60825-2]. It should be noted that, at receiving interface R1, LOS-P will also occur, but not LOS-O and, therefore (if present), the power pumped backwards by Raman amplifiers into the lower link at receiving interface R1 does not have to be reduced.

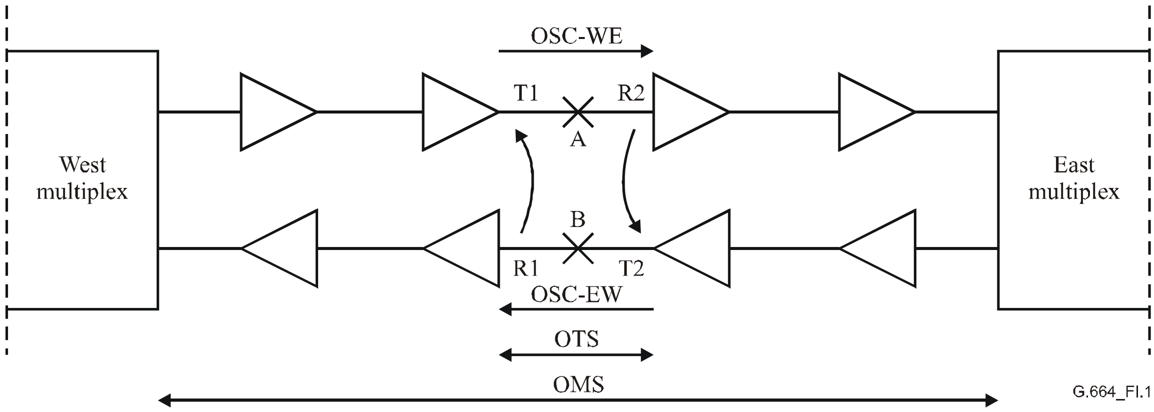


Figure I.1 – Description of APR capability in the case of loss of continuity within a cable in a configuration with co-propagating OSC

As soon as the continuity of the fibre cable is restored at point A, LOS-O will disappear at receiving interface R2, and full OSC communication will be restored. Now, full connectivity is guaranteed. The power at transmitting interface T2, and the reverse pumping (when present) at receiver interface R2, can be immediately restored while OSC-EW sends a signal to R1 that the power at transmitting interface T1 can be restored as well. The case that a loss of fibre continuity occurs at point B, as shown in Figure I.1, is fully equivalent to a loss of fibre continuity at point A.

In the case that there is a simultaneous loss of continuity in both directions (at both points A and B), at both receiving interfaces R1 and R2, LOS-P and LOS-O will occur, triggering immediate reduction of power at both T1 and T2 and reverse pump power at both R1 and R2. In all cases, the optical power associated with the OSC will be maintained.

Order of actions/events:

1) loss of continuity at point A;
2) LOS-O AND LOS-P at R2;
3) reduced power at T2 AND reduced reverse pump power at R2 AND OSC-EW signalling of loss of continuity towards R1;

4) LOS-P AND receiving message by OSC-EW at R1;

5) LOS-P OR receiving message by OSC-EW at R1 initiates reduction of power at T1;

6) link power reduced to safe level;

7) repair of link continuity at point A;

8) clearing of LOS-O at R2, indicating full restoration of both WE and EW OSC links, thus confirming link continuity;

9) restore reverse pump power at R2 AND forward power at T2 AND OSC-EW signalling of repair of link continuity to West multiplex;

10) LOS-P clearing at R1 AND R1 receiving repair message by OSC-EW;

11) restoring forward power at T1;

12) clearing of LOS-P at R2;

13) link operation completely restored.

I.3 Description of APR procedure using counter-propagating OSC

In Figure I.2 a multichannel configuration is shown where, in the upper link in addition to "traffic", an OSC called OSC-EW, is present on the link. Contrary to the configuration described in I.2, this OSC is travelling in the opposite direction from the East multiplex to the West multiplex. In the lower link, an OSC called OSC-WE is travelling from the West multiplex to the East multiplex, also in a direction opposite to the traffic. Within the context of this example, this configuration is referred to as a counter-propagating configuration.

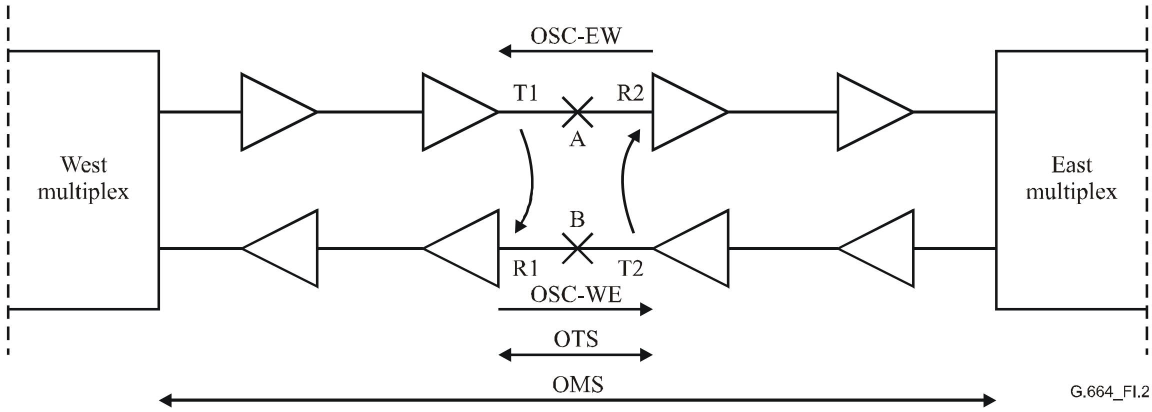


Figure I.2 – Description of APR capability in the case of loss of continuity within a cable in a configuration with counter-propagating OSC

In the case that loss of continuity occurs at point A in the OTS indicated in Figure I.2, at receiving interface R2, LOS-P (LOS payload) and at transmitting interface T1 LOS-O (LOS overhead) will occur. Then, immediately the optical power at transmitting interface T1 and the reverse pump power at R2 (when present), should be reduced sufficiently to meet the appropriate hazard level. Then the upper link is safe and there is no necessity to shut down the lower link because each link can be separately managed.

The powers at both T1 and R2 should be reduced within a certain time, depending on several parameters, such as the operational power within the fibre, fibre diameter and wavelength. Details are provided by [IEC 60825-1] and [IEC 60825-2].

As soon as the continuity of the fibre cable is restored, LOS-O will disappear at transmitting interface T1, and full OSC communication will be restored on the upper link. Now full connectivity is guaranteed, which will be communicated from West to East multiplex by OSC-WE on the lower link. The power at transmitting interface T1, and the reverse pumping (when present) at receiver interface R2, can be immediately restored.

The case that a loss of fibre continuity occurs at point B, as shown in Figure I.2, is fully equivalent to a loss of fibre continuity at point A.

In the case that there is a simultaneous loss of continuity in both directions (at both points A and B), at both receiving interfaces R1 and R2 LOS-P will occur and at both transmitting interfaces T1 and T2 LOS-O will occur. This will trigger immediate reduction of power at both T1 and T2 and reverse pump power at both R1 and R2. In all cases, the optical power associated with the OSC will be maintained.

Order of actions/events:

1) loss of continuity at point A;
2) LOS-O at T1 AND LOS-P at R2;
3) reduced power at T1 AND reduced reverse pump power at R2;
4) link power reduced to safe level;
5) repair of link continuity at point A;
6) clearing of LOS-O at T1, indicating full restoration of EW OSC link, thus confirming link connectivity;
7) restore forward power at T1 AND OSC-WE signalling of repair of fibre continuity to East multiplex;
8) restore backward power at R2;
9) LOS-P clearing at R2;
10) link operation completely restored.

Appendix II

Description of automatic laser shutdown/automatic power shut-down (ALS/APSD) procedures for single-channel point-to-point SDH systems

(This appendix does not form an integral part of this Recommendation.)

II.1 Introduction

In the first version of this Recommendation, the ALS procedure described in this appendix was part of the main body. Because of changes over time (since 1984) in [IEC 60825-1] and [IEC 60825-2], the ALS procedure no longer provides the optical safety as originally intended. In particular, the use of a repetitive pulse to restart the system is considered no longer appropriate for reasons given below. Furthermore, the optical power levels specified in [ITU-T G.957] all are within the Hazard level 1 category (fully safe) and those in [ITU-T G.691] are all within Hazard level 1M, as well as previous Hazard level 3A (safe without viewing aids).

Because the ALS procedure has been widely deployed in SDH terminal equipment over the past years, it is captured in clause II.2 for historical purposes. Furthermore, a modified ALS procedure in the case of line amplifiers is described in clause II.3. In this case, longer restart pulses are used, which makes the procedure even less appropriate.

The ALS procedure was originally defined in 1989 using a version of [IEC 60825] from 1984. At that time, the optical power levels defined in [ITU-T G.957] for both 1310 nm and 1550 nm windows were regarded above Hazard level 1.

Since that time, [IEC 60825-1] has undergone various modifications. The latest official version is Edition 2.0 (2007-03).

In particular, for the case of a 2.25 second restart pulse, the accessible emission limits (AELs) have been modified in the exposure time range of interest (0.35 to 10 s).

It can be calculated from the formula given in [IEC 60825-1] that, for a 1550 nm system using ALS and stating Hazard level 1, the maximum optical power during a 2.25 second restart pulse may "only" be 1.7 dB above the Hazard level 1 limit for continuous power. If the restart pulse power (which may be equal to full operational power) goes above this value, then the system will exceed Hazard level 1, e.g., it may become Hazard level 1M instead. This means that, in this case, using the ALS procedure only reduces the hazard level in a very limited power range of 0 to 1.7 dB above the Hazard level 1 limit of continuous power.

As an example: an SDH system using a booster amplifier with output power of +16 dBm (Hazard level 1M or previously 3A), will still be 1M when using ALS. Thus the hazard level will not be lower when using ALS, in this case.

Another more specific example is for application codes U-16.2 and V-64.2b in [ITU-T G.691], where the transmitter output power range is specified as +12 to +15 dBm. This is Hazard level 1M with AND without ALS.

However, in the case of single-channel systems with high operational power levels (up to the Class 3B limit), using the ALS procedure can result in a reduced hazard level of 1M (provided the requirements in [IEC 60825-2] on shut-down and restart are met).

II.2 Single-channel point-to-point SDH without line amplifiers

In this clause, an automatic laser shut-down (ALS) and restart procedure for single-channel SDH systems is described which was originally designed to support optical safety requirements on transversely compatible SDH optical interfaces. Accommodation of this procedure, in the case of the additional presence of optical line amplifiers, is described in clause II.3.

NOTE 1 – As mentioned in clause II.1, a lower hazard level is generally not achieved because of the full operational power within a restart pulse. The exact hazard level, when using ALS, depends on several parameters, such as operational power within the fibre, fibre diameter and wavelength. Details are provided by [IEC 60825-1] and [IEC 60825-2].

This ALS procedure consists of two parts, a shut-down and a restart part. "Complete" shut-down is used to trigger LOS in the relevant receivers. In particular, the definition of the restart part is critical in the case of transversely compatible interfaces (two different equipment vendors at the ends of the link). In the ALS procedure, a regularly transmitted, short restart pulse at full operational optical power is used to check whether the link has been repaired. Full operational power is required to clear LOS defects in the relevant receivers.

NOTE 2 – The ALS procedure specified in this clause, in particular the associated time constants, is designed to operate correctly only if no additional equipment is present between MPI-S and MPI-R (see Figure II.2).

In its most general sense, an SDH single channel system can consist of two terminals (East and West) and a chain of several regenerators, as shown in Figure II.1. The optical interfaces between these terminals and regenerators are supposed to be compliant with [ITU-T G.957]. Furthermore, optical boosters and preamplifiers might be present to enhance the power budgets on these interfaces.

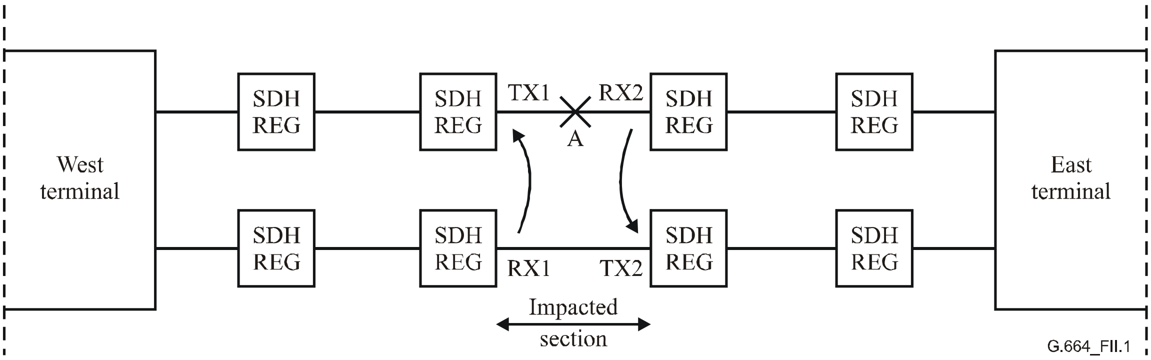


Figure II.1 – Clarification of ALS operation in the case of loss of continuity within a cable in a chain of SDH regenerators

The reference configuration for a single section from this configuration is shown in Figure II.2.

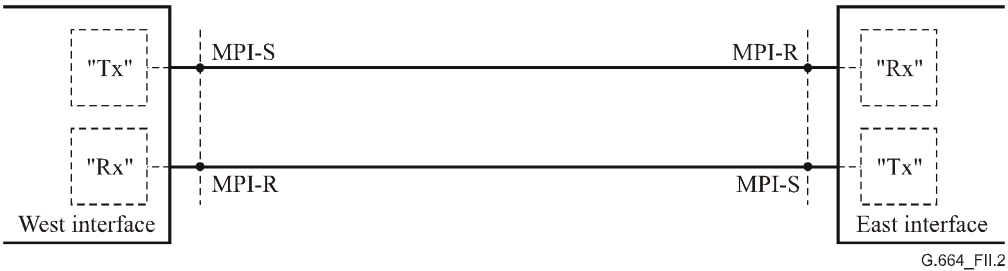


Figure II.2 – Reference configuration for description of ALS capability

In Figure II.2, "Tx" can be either a transmitter according to [ITU-T G.957] (specified at reference point S) or it may include optical amplification to increase the output power (i.e., OAT or BA in combination with suitable adaptation of equipment according to [ITU-T G.957]). Furthermore, "Rx" can be either a receiver according to [ITU-T G.957] (specified at reference point R) or it may include optical preamplification (i.e., OAR or PA used in combination with a suitable adaptation of equipment according to [ITU-T G.957]). The "West" and "East" interfaces may be part of terminal equipment or of electrical regenerators.

In the case that loss of continuity happens at point A of Figure II.1, the consecutive Loss of Signal defect (dLOS) at "conventional" receiver RX_2 is used to shut down the output of "conventional" transmitter $TX_{2,}$ which is the adjacent transmitter in the opposite direction. This in turn leads to dLOS in "conventional" receiver $RX_{1,}$ which in its turn shuts down "conventional" transmitter TX_1. After shut-down, the output power of the transmitter shall be sufficiently low to generate dLOS at the receiver side. The definition of LOS is given in [ITU-T G.783]. In all cases, only the impacted section may be shut down, which is clarified in Figure II.1.

After at least 500 ms of continuous presence of the LOS defect, the actual shut-down command will be activated which shall result in reduction of the optical output power at MPI-S within 800 ms from the moment loss of optical signal occurs at MPI-R.

NOTE 3 – The complete shut-down of the "conventional" transmitters is not required by [IEC 60825-2], but is necessary in this case, because otherwise LOS might not be detected in the "conventional" receiver. The remaining output power of the involved optical amplifiers after shut-down of the "conventional" transmitters shall be within Hazard level 1M for equipment in restricted locations, noting that this does not exclude reduction to within Hazard level 1 (including the possibility of complete shut-down).

It is assumed that the optical boosters operate in a master/slave configuration, i.e., when the input signal vanishes, the output should be shut down, and when the input signal returns, the output power should be restored. It will not be necessary to shut down the output of the preamplifier in the case that it is within Hazard level 1 or 1M under reasonable foreseeable conditions as clarified in [IEC 60825-2].

Figure II.3 shows a conceptual diagram of the automatic laser shut-down and restart procedure, for which it should be noted that this figure is not intended to be a state diagram. A clarification of the associated shut-down timing requirements is shown in Figure II.4.

NOTE 4 – If automatic laser shut-down is implemented, it should not impair fault sectionalization capability in the case of loss of signal at the transmitter or the receiver due to causes other than a cable break.

When the continuity of the cable has been repaired, either an automatic or a manual restart according to Figure II.3, at TX_1 or TX_2, is necessary to restore transmission. The principle for the restart of a shut-down system is the use of a restart pulse, which shall be within Hazard level 1M (not excluding Hazard level 1) to minimize risk of exposure to hazardous power levels.

NOTE 5 – It is not implied by this text that both an automatic and a manual restart be implemented simultaneously.

NOTE 6 – In Figure II.3 the minimum delay between the restart pulses is specified to be 100 s, but in order to have backwards compatibility with no longer existing Recommendations, a minimum delay of 60 s can be used, if the optical power within the restart pulse is 3 dB lower than for what is allowed for the 100 s minimum delay time. [IEC 60825] requires that within a 100 s period, the total energy of all pulses has to be accounted for to calculate the hazard level.

The activation response time of the "transmitter"/"receiver" combination (as shown in Figure II.1), measured from "receiver" input (point MPI-R) to transmitter output (point MPI-S) should be less than 0.85 s. This response time of 0.85 s refers to the time difference between the moment light enters the "receiver" at point MPI-R and the moment the "transmitter" starts light emitting at point MPI-S in the case that the "transmitter" is in the shut-down condition. The optical amplifiers shall restart sufficiently slow (within the above-mentioned activation response time) to avoid, as much as possible, optical surges.

The maximum deactivation time of booster and preamplifiers shall be 100 ms. A booster and preamplifier shall have a maximum activation time of 100 ms and 300 ms respectively.

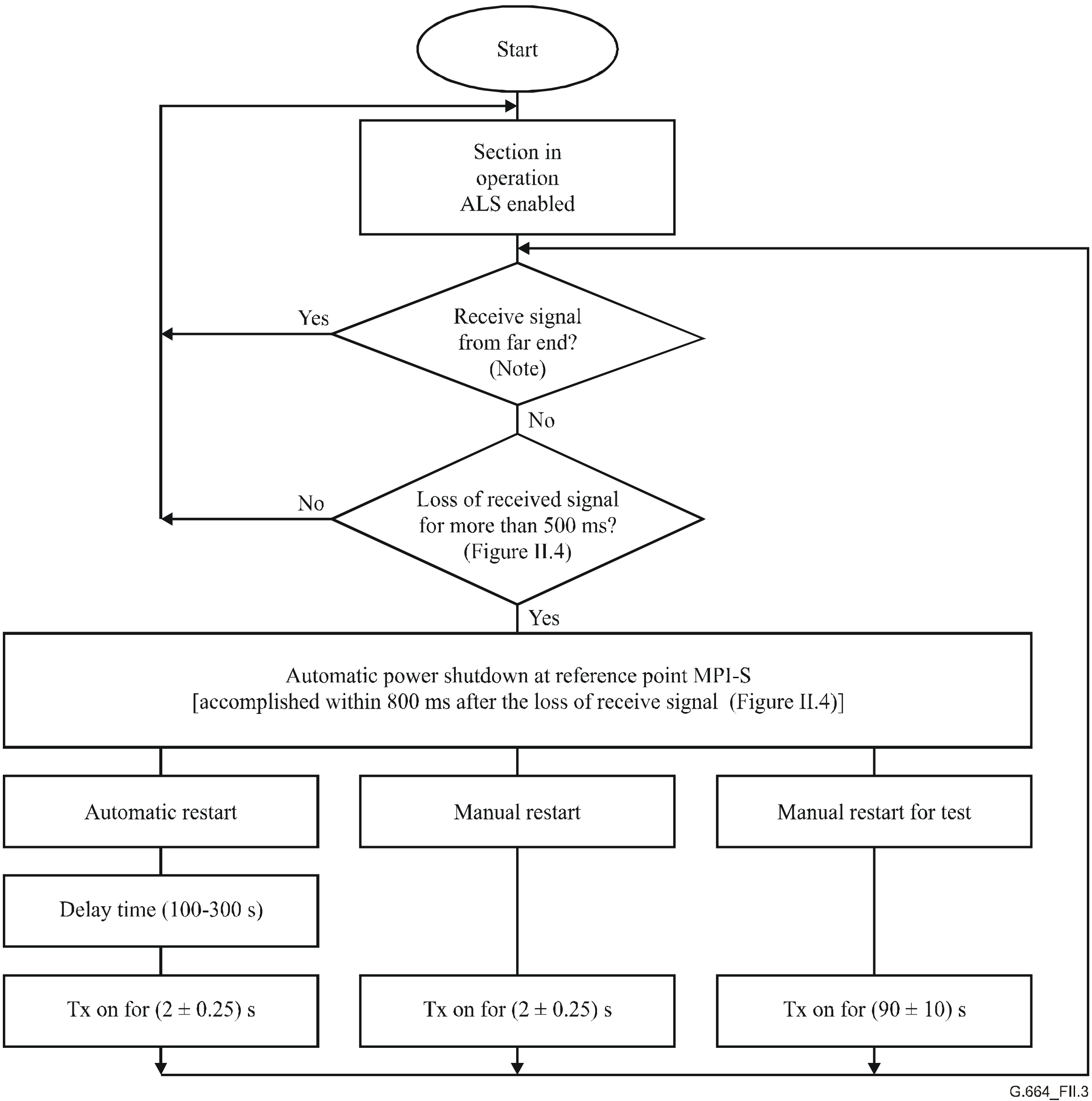
The various time constants are summarized in Table II.1.

For test and monitoring purposes, it is possible to override the shut-down mechanism by switching on the laser manually.

NOTE 7 – During "manual restart for test", specific care must be taken to assure connectivity to avoid exposure to hazardous optical levels, particularly in the case of Hazard level 3B for equipment in restricted locations. Furthermore, to avoid accidental overexposure, it is recommended to use a sufficient delay, e.g., 100 s, between individual manual restart pulses.

"Manual restart" or "Manual restart for test" can only be activated when the laser is shut down.

In the case that protection switching in the electrical domain (e.g., MSP or MSSPRING) is implemented, a working channel receiver should shut down a working channel transmitter. Similarly, a protection channel receiver should shut down a protection channel transmitter.



NOTE – "Receive signal from far end?" is also active when the transmitter is in the shutdown situation.

Figure II.3 – Automatic laser shut-down and restart concept including optional test procedure

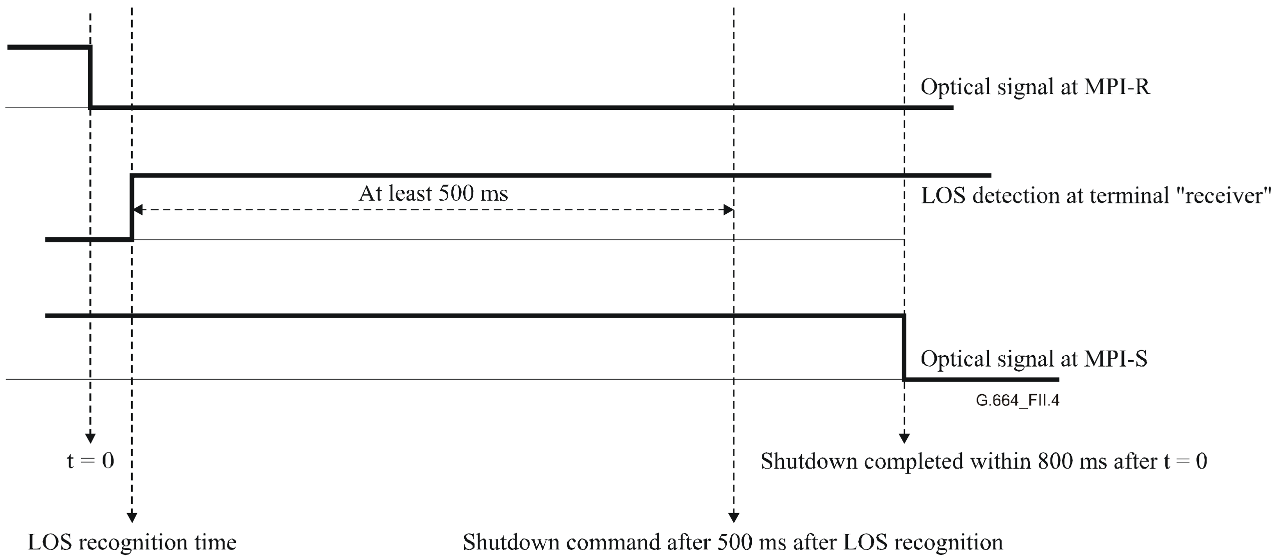


Figure II.4 – Clarification of shut-down timing requirements

Table II.1 – Time constants for automatic shut-down

Time constant	Reference points	Value	Note
Terminal response activation time	MPI-R to MPI-S	850 ms max	
Terminal deactivation time	MPI-R to MPI-S	(500-800) ms	1
BA deactivation time	R' to MPI-S	100 ms max	
BA activation time	R' to MPI-S	100 ms max	2
PA deactivation time	MPI-R to S'	100 ms max	2
PA activation time	MPI-R to S'	300 ms max	2
Pulse length for manual and automatic restart	N/A	(1.75-2.25) s	
Pulse repetition time for automatic restart	N/A	(100-300) s	
NOTE 1 – The LOS condition applies even in the presence of ASE. NOTE 2 – Reference points S' and R' are specified in ITU-T Rec. G.662.			

II.3 Single-channel point-to-point SDH with line amplifiers

In some specific cases of single-channel point-to-point SDH systems, optical line amplifiers are inserted between conventional SDH terminals and regenerators (in addition to the insertion of boosters and preamplifiers) in order to further increase the physical distance between these terminals and regenerators. The reference configuration for this application is shown in Figure II.5. Also, in this case, the line amplifiers should act in a master/slave configuration, as already clarified in clause II.2.

Because of backwards compatibility with no longer existing Recommendations, the techniques described in this clause are allowed to enable safer working conditions on SDH systems with optical line amplifiers with operational output powers of Hazard level 3B in the case of restricted locations.

When loss of continuity occurs at some point between MPI-S and MPI-R (see Figure II.5) not only the impacted section will be shut down, but all sections between MPI-S and MPI-R. The line amplifiers do have their specific activation and deactivation response times (e.g., a maximum activation time of 300 ms and deactivation time of 100 ms). Therefore, the shut-down and restart time constants, as specified under clause 6.2, are not sufficiently long to ensure proper functioning of the ALS procedure.

In order to avoid exposure to hazardous optical power levels, all amplifiers (boosters and line amplifiers) shall have sufficiently short deactivation times to accommodate shut-down of all amplifiers between MPI-S and MPI-R within 3 s from the moment the actual connection interruption occurs.

NOTE 1 – Depending on the actual operational power, the 3 s shut-down time (defined in the past) might not be fast enough. A check against [IEC 60825-1] and [IEC 60825-2] is recommended.

In order to allow automatic restart of SDH systems with line amplifiers, which are in shut-down condition, it may be necessary to increase the restart pulse length (defined in clause II.2) beyond the maximum of 2.25 s (to e.g., 9 ± 0.5 s), the actual value depending on the number of line amplifiers present. The definition of the revised restart pulse length, depending upon the actual number and output power of inserted line amplifiers, is considered outside the scope of this Recommendation. This restart pulse shall be of Hazard level 1M in the case of restricted locations.

NOTE 2 – The actual power level to ensure Hazard level 1M depends on the length of the restart pulse, i.e., shorter restart pulses can have a higher power level than longer pulses.

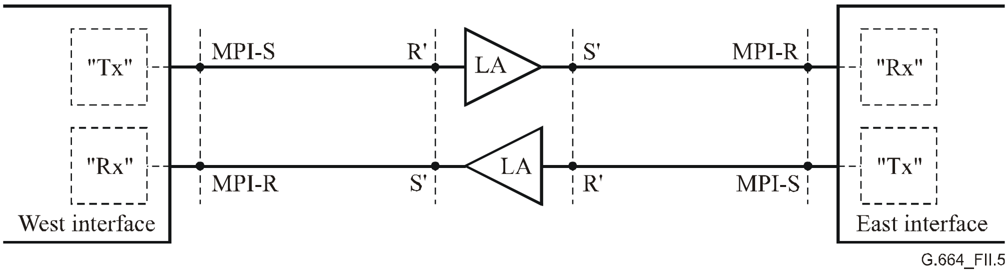


Figure II.5 – Reference configuration for description of ALS capability in the case that line amplifiers are present

Appendix III

Example(s) of APR architecture for OAN systems based upon Raman amplification

(This appendix does not form an integral part of this Recommendation.)

III.1 Further considerations on APR procedures in Raman amplified PON reach extenders

In the current in-force [ITU-T G.984.x] series an OSC is not defined.

Some existing OTN APR procedures rely on the detection of both LOS on the data channels and LOF on the OSC. After APR systems detect LOS on the data channel and/or LOF on OSC they reduce the power of lasers and other active components to the level that is below safety level.

On account of the fact that in PON systems the 1310 nm US data signals operate in burst mode for Raman GPON extension systems and because the PON is a point-to-multipoint topology, the use of the GPON loss of signal needs to be addressed with some care.

A suitable trigger for an APR in the splitter and feeder part of the GPON reach extender (RE) may be the "upstream LOS" alarm from the PON equipment. This alarm event happens when all the ONU upstream transmissions are lost within a very short time. All OLTs can detect this, and it should be detectable in a relatively short period of time, e.g., about 100 ms. The primary factor to determine the speed of detection is the maximum idle time of each ONU, which can be controlled by the OLT's scheduling process. This LOS detection speed may not be fast enough to satisfy the shutdown requirements from [IEC 60825-2]. In the case of Raman-pumped PON RE, the OLT should be configured to reliably detect the "upstream LOS" within the requisite time interval to achieve reliable APR. In the case of the Raman-based RE described in Amendment 2 to [ITU-T G.984.6], the operating wavelength of the Raman pump (1240 ± 0.5 nm) is such that for most power levels within the allowed range, the required shutdown time is less than would normally be achieved by the upstream LOS mechanism. In this case, an alternative APR trigger must be provided that is sufficiently fast. One candidate mechanism for this is to provide an optical auxiliary channel (OAC) to verify link connectivity over that part of the link where APR is required.

Bibliography

[b-ITU-T G-Sup.39] ITU-T G-series Recommendations – Supplement 39 (2006), *Optical system design and engineering consideration.*

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Printed in Switzerland
Geneva, 2013