TC57

Position of IEC TC57 (electrical utilities) towards ITU on the transformation of UTC into a linear time scale (abolishing leap seconds)

proposed by the Swiss National Committee TK57

Geneva, Switzerland, 6 October 2014

Hubert Kirrmann, Switzerland, IEC TK65 chairman

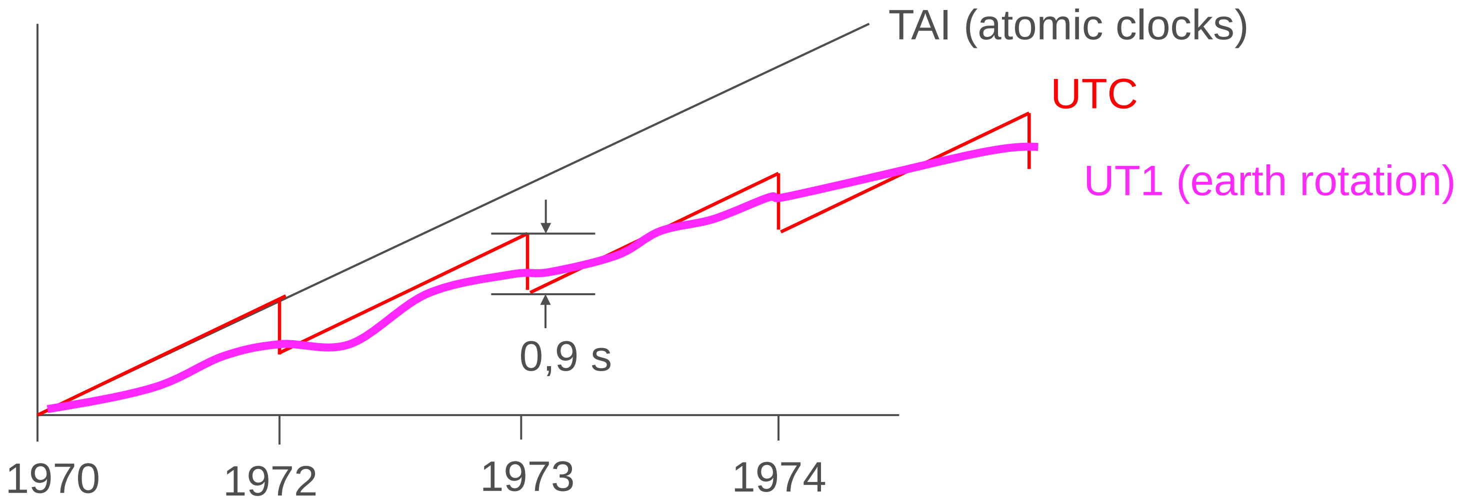
Time Scales

There exist several time scales, in particular:

- TAI (Temps Atomique International) is the scientific time scale based on a network of atomic clocks. Time is continuously and monotonically incremented and will never be reset or discontinued. It is the base of all other scales.
- UT1 (Universal Time based on the mean earth rotation) is a variable time scale that can be used for stellar navigation or astronomy. Since the earth rotation slows down, UT1 lags behind TAI by about 0.5s a year.
- UTC is the legal time. It is the base for the time zones (CET, ET,…) of all countries. It indicates approximately 12:00:00 at solar noon in Greenwich at the Spring equinox (it was formerly called Greenwich Mean Time).
  The Bureau International des Poids et Mesures (BIPM), Paris, is responsible for the definition of UTC.

- **Back in the 1970's, the UTC and TAI scales were identical for a few years.**

Leap seconds



The earth rotation constantly slows down (tidal effect), days became longer.

When the difference between UTC and UT1 exceed 0,9 s (after about 1,5 years), the BIMP (Bureau International des Poids et Mesures) adjusts UTC by letting all clocks in the world insert a leap second, so the last minute of a day (in principle December 31 or June 30) lasts 61 seconds (the reverse case is also possible, but is very unlikely).

Leap seconds cannot be anticipated, irregularities of the earth's rotation are unpredictable.

In 2014, UTC lags behind TAI by 36 seconds:
when TAI time says it's 2011-02-04 12:00:00,
UTC says it is only 2011-02-04 11:59:24.

TAI time can be calculated from UTC time with a table of all elapsed leap seconds, but UTC cannot be predicted for a given TAI, since BIMP introduces leap second arbitrarily.

- http://en.wikipedia.org/wiki/Leap_second

Absolute time usage in electrical utilities

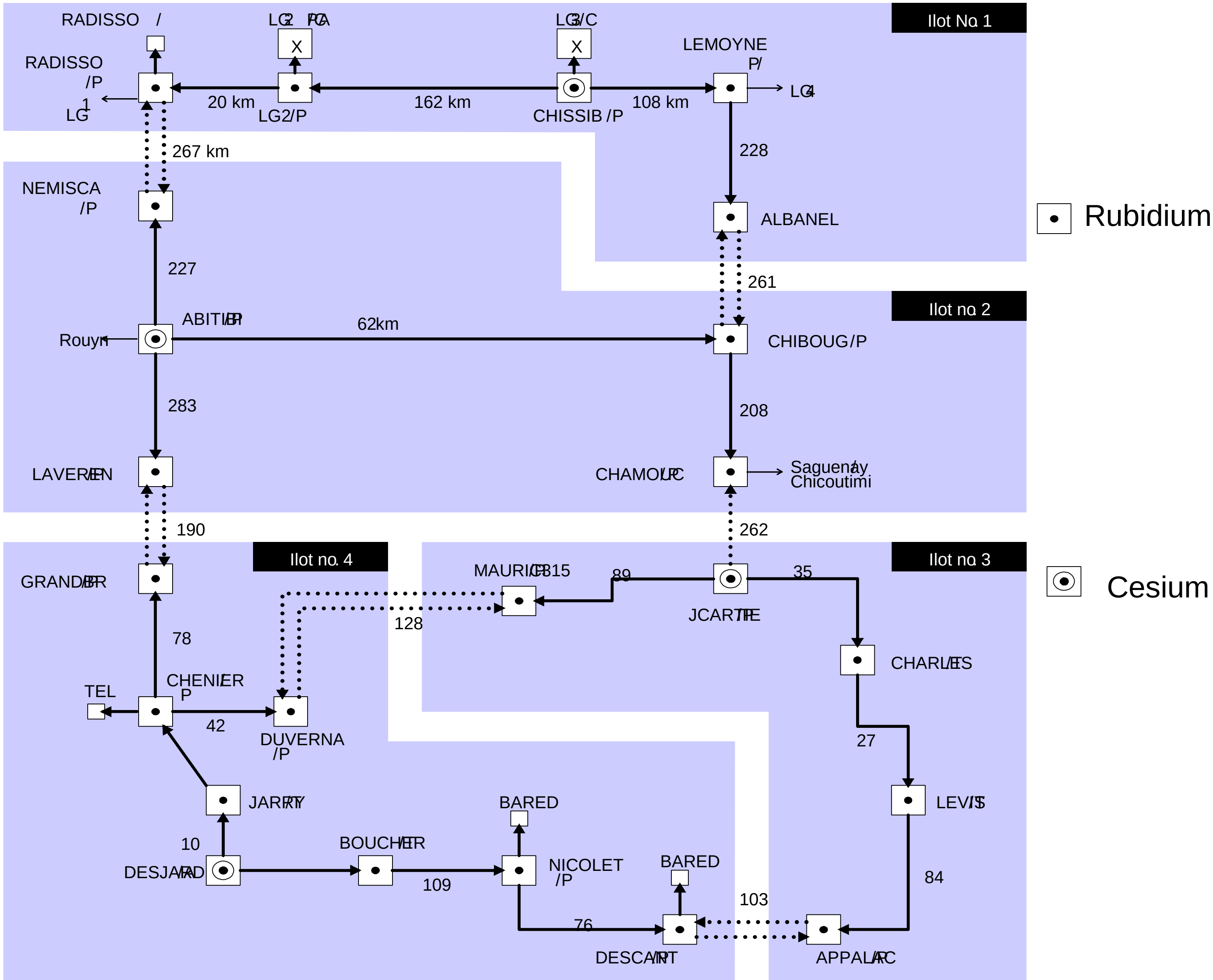
Event time-stamping
Reconstruction of events (grid disturbances) require sub-millisecond accuracy.

Line differential protection
Relays at the ends of a high-voltage line exchange their current values with the other ends, time-stamped to better than 4 us. When communicating over a Wide Area Network, absolute time on both sides allow to align sampled values, relative time would require cross-synchronization, which does not work with packet switched networks.

Phasor measurement units
Blackout prevention relies on phase measurement units (PMUs) for current and voltage (PMUs) located strategically in the electricity grid. All PMUS over the different countries send the phasor values to a control center, which computes a grid model and detect abnormal phase deviations. A wrong decision could lead to a load shedding of entire cities.

PMUs time-stamp the phase values with phase error of <1% (accuracy <10 µs).

Example: Hydro-Quebec



Utility protocols time representation

Protocol	Epoch	Rollover	Base	Seconds	Fractions	Resolves
ICMP	midnight	none	UT	Uint32	milliseconds	1 ms
SNTP same as Excel	1900-01-01	2036	UTC	Uint32 Uint32	binary	232 ps
NTP v3 NTP v4	1900-01-01 1900-01-01	2036 ∞	UTC UTC	Int32 Int32 Int64 Int64	binary binary	232 ps 2 as
Unix (Posix)	1970-01-01	2038 (2106)	UTC	Int32 (Int64)	Int32	232ps
DNP3.0	1970-01-01	6950	UTC	Uint48	milliseconds since epoch	1 ms
IEEE C37.118	1970-01-01	2106	UTC	Uint48	Int24	60 ns
IEC 61850-7-2 TimeStamp	1970-01-01	2106	UTC/TAI	Uint32	Uint24	60 ns
IEC 61850-8-1 UtcTime	1970-01-01	2106	UTC/TAI	Uint32	Uint24	60 ns
IEC 61850-7-2 EntryTime ITU ASN.1 TimeOfDay	1984-01-01 1984-01-01	none none	UTC UTC	BINARY-TIME [6] OCTET STRING[6]		
GPS	1980-01-06	2137	TAI+19s	week + seconds in week		
IEEE 1588 PTP	1970-01-01	2036	TAI	Uint48	Int32 scaled ns	
IRIG B	0	∞	UTC	SS:MM:HH:DDD <control> <binary seconds> YY LSP LS DSP DST TO TO CTQ		

Most protocols specify «UTC» as the time base, but did not care about leap seconds

What can happen

The time-stamping for grid measurement values has **no leap second indication**. Therefore, during a leap second, it is not possible to reconstitute the sequence of events since events coming later have an earlier time stamp. Logic that depends on the sequence is fooled.

If a PMU loses its GPS antenna (e.g. as a consequence of an earthquake or jamming), it runs on holdover, for some minutes if it has a TXCO. Better substations commutes to a back-up clock, e.g. a Rubidium clock with a high stability. This enables it to keep on sending phasor values for hours or even weeks in a contingency case, until repair takes place.

If during repair time the GPS announce a leap second, the Rubidium clock will not be aware of if and keeps using the old time frame. This will confuse the WAMPAC system and can cause wrong actions that worsen the contingency. This situation can be provoked intentionally.

In some network, GPS are not allowed. In this case all synchronization is performed by Rb or Ce clocks. The leap seconds must be entered by hand, an error-prone process. It is often not possible to control that the clock will insert the leap second properly, months after entering the jump.

Why now?

Electrical grids are increasingly dependent on automatic mechanisms for outage prediction and grid restoration.

With the deployment of WAMPACs (automatic grid restoration) there is no human intervention any more.

Already on June 30, 2012, there was a disturbance in a grid, although WAMPACs was only at the prototype level.

This could have worse consequences with large-scale deployment of WAMPACs.

Handling of leap seconds

- All standard documents in IEC specify "UTC" as time base and all public bids ask for it. Leap seconds are implicit, but the bid writers are not aware of it.
- No time representation in IEC is able to handle leap seconds, so the values of timestamps do not increase monotonically with time.
- Some time distribution systems announce leap seconds (NTP, SNTP, IEEE 1588), other do not (DNP3) – the discrepancy can last for hours.
- Some time distribution systems indicate the current number of leap seconds since 1970 (IEEE 1588), other do not (NTP)

- Specific problems:
- How to calculate a time difference $\Delta t = (t_2 - t_1)$ which contains leap seconds ?
- How to relate events recorded by different utilities over a leap second ?
- How to interpret historical data without knowing the reference time ?
- How to ensure all devices use the same time reference frame ?

See the discussion at ITU:

- http://itu4u.wordpress.com/2013/10/11/time-to-leave-leap-seconds-behind/

NTP: what does the standard say:

“NTP timestamps are represented as a 64-bit unsigned fixed-point number, in seconds relative to 0h on 1 January 1900. The integer part is in the first 32 bits and the fraction part in the last 32 bits.

This format allows convenient multiple-precision arithmetic and conversion to Time Protocol representation (seconds), but does complicate the conversion to ICMP Timestamp message representation (milliseconds). The precision of this representation is about 200 picoseconds, which should be adequate for even the most exotic requirements.”

There is no mention of leap seconds since at the time NTP was defined, UTC and TAI were the same.

Those who introduced leap seconds after 1970 violated the specification.

Later versions of NTP define a handling of leap seconds.

Conclusion

All technical systems in utilities and industry should rely on a linear time scale.

TAI is such a linear time scale, UTC is not and only usable as human representation.

However, many standard documents refer to “UTC”, meaning an absolute, monotonic time scale, since they were written at a time where there was no difference between UTC and TAI.

Customer keep on requesting “UTC” since they are ignorant of the difference, and think that UTC is the successor of GMT.

Since it is not possible to rewrite the old standards such as NTP, it is necessary to restore the linear time scale to stop inserting leap seconds.

The Swiss National Committee asks TC57 plenary to intervene at the ITU-R Study Group 7's WP7 to return UTC to a linear time scale without leap seconds.

Technical details

Use of TAI in the IEC 61850 standard

- IEC 61850 standards specify the use of UTC, but allow also a time representation of TAI (leapSecondsKnow = false) == TAI

- IEC 61850-90-5 and IEC 61850-90-4 recommend the use of TAI rather than UTC (as received over IEC 61588).

- IEC TC57 WG10 should recommend to use TAI in all time representations in future developments.

- This recommendation should also apply to IEEE C37.118 synchrophasor transmission (but IEEE will probably not change it).

Example: NTP format

```
                     1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9  0  1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|LI | VN  |Mode |    Stratum    |     Poll      |   Precision   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                          Root  Delay                          |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                       Root  Dispersion                        |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Reference Identifier                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                   Reference Timestamp (64)                    |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                   Originate Timestamp (64)                    |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                    Receive Timestamp (64)                     |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                    Transmit Timestamp (64)                    |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                 Key Identifier (optional) (32)                |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
|                                                               |
|                 Message Digest (optional) (128)               |
|                                                               |
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Leap Indicator (LI): This is a two-bit code warning of an impending leap second to be inserted/deleted in the last minute of the current day. This field is significant only in server messages, where the values are defined as follows:

LI Meaning

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0 no warning

1 last minute has 61 seconds

2 last minute has 59 seconds

3 alarm condition (clock not synchronized)

DNP 3.0 leap second issue

10.3 Time synchronization

10.3.1 General

DNP3 outstation devices are often required to time tag events to the nearest millisecond, and some devices are required to automatically freeze accumulators or perform some activity at specific times. In order to support these time-related activities, an outstation shall have a dependable time source. It may use a local source, such as a GPS receiver, or it can request time synchronization from the master using DNP3 messages. An outstation with access to, and using, an accurate local time source may choose not to set its current time with the time that it receives in a time synchronization message from the master, but the outstation shall reply as if it had set its local time from the time in the message.

10.3.2 Time base

DNP3 time corresponds to Universal Coordinated Time (UTC).[28]

UTC does not shift with daylight saving (summer) time and does not change depending on the local time zone. Thus, events that occur at separate geographical locations, but at the same instant, are reported with identical DNP3 time values.

UTC, and therefore DNP3 time values, are adjusted appropriately when leap-seconds are added or subtracted by the International Earth Rotation Service (IERS)[29] so that UTC agrees with astronomical time based on the rotation of the earth.

Values within DNP3 time objects contain the number of milliseconds from the DNP3 time epoch, which is defined as 1970-01-01T00:00:00.000[30] UTC. The DNP3 time epoch assumes there were exactly 86 400 000 milliseconds in every day during the intervening years (i.e., it does not include leap-seconds).

DNP3 cannot represent times that occur within the 1000 millisecond period when a leap-second is added to UTC. Devices are expected to continue counting milliseconds as usual during periods of leap-second adjustments until the outstation is re-synchronized. There may be an uncertainty in the DNP3 time measurement during this interval, and time stamps recorded in that period may be in error.

[28] The effective date for using the UTC time base is 1 January 2008. Prior to this date, DNP3 did not require a specific time reference.
[29] http://www.iers.org/.
[30] The date format is YYYY-MM-DDThh:mm:ss.sss where ss.sss represents seconds and milliseconds and where a capital letter T separates the date and time fields. This notation conforms to ISO 8601 [B10].

Time to leave leap seconds behind?

Leap seconds could be abolished soon (if it would not be for the opposition of astronomers and traditionalists) http://en.wikipedia.org/wiki/Leap_second.

October 11, 2013 · by itu4u · in ITU News Magazine · 2 Comments

The World Radiocommunication Conference will decide in 2015

Coordinated Universal Time (UTC) is the international standard time-scale for all practical timekeeping in the modern world. UTC is calculated using atomic clocks. Its historical counterpart, Universal Time (UT1), is an astronomical time-scale based on the observation of the Earth's rotation.

But the Earth's rotation rate is irregular, and has been generally slowing down. So, since 1972, these two time-scales have been kept in step by adding a leap second to UTC whenever necessary to keep the difference between them to less than one second, as desired by the scientific community. An extra 25 seconds have been added to UTC and clocks around the world so far.

With the advent of global navigation satellite systems in particular, options for revising the definition of UTC and the future of the leap second have been keenly debated in various international organizations, notably ITU which is responsible for defining UTC. Some countries have called for an end to leap seconds, but others disagree arguing that the present definition of UTC with leap seconds is satisfactory.

World Radiocommunication Conference in 2015

IEC TC57 WG10 decision

Decision on 2014-02-28 (Montpellier)

There is general agreement on the recommendation.

This matter should be brought to the TC57 plenary in Tokyo.

IEC TC57 plenary position: proposed text

“IEC TC57 supports the conversion of UTC into a linear time scale as a means to avoid ambiguities in time stamping in electrical grids and to simplify communication protocols.”

Justification: as UTC was introduced in the 1970, utility protocols defined UTC as the time base for time-stamping events and values. At that time, it was not realized that leap seconds would be introduced, TAI was unknown.
Indeed, most utility protocols specify time as «the number of seconds since January 1st, 1900», without mention of leap seconds. UT1 has no relevance for utilities, not even for solar energy.
Many legacy protocols do not have means to announce leap seconds.
Other protocols such as IEEE 1588 announce leap seconds but applications cannot handle samples that come later in time but have an earlier time-stamp during the leap second. Tracing events back in time across a leap second is difficult due to the discontinuity in the time scale.
As synchrophasors are being widely deployed, a grid disruption due to false alarms resulting from misinterpreted time stamps across leap seconds cannot be excluded.
It is practically impossible to test the influence of a leap second on the grid control and protection until one occurs.
Although WG10 already now recommends to use TAI, most existing documents specify UTC and legacy devices cannot be modified. “