Five Good Reasons to Abandon Synchronous Time Control

Yann G. Rebours, *Member, IEEE*, Julien Pestourie, and Etienne J. Monnot

***Abstract*—Time control maintains the average electrical frequency to its nominal value over the long run. This control currently suffers from numerous accepted beliefs that are deemed to justify this practice. This paper discusses these beliefs and highlights various reasons in favor of abandoning time control. In particular, time control exhibits a limited value compared to increased costs due to a higher operation complexity and a lower security. If time control has to be kept, this paper shows that current operational procedures should at least be improved in order to increase system security.**

***Index Terms*—ancillary services, control, frequency, reserves, time**

I. Introduction

TIME control maintains the power system average electrical frequency at its nominal value (e.g., 50 or 60 Hz). This paper reviews and discusses arguments that are deemed to justify such a control. In the introduction, the basic concepts related to time control are defined. Part II then describes the technical features of time control and its impact on frequency control. Last, Part III gives five good reasons to abandon time control.

A. Frequency Control

To maintain generation and consumption balanced at any time, three controls are performed by the Transmission System Operators (TSOs), mostly with the help of generating units. First, *primary frequency control* is a local automatic control that adjusts the active power generation of generating units and the consumption of controllable loads to restore quickly the balance between load and generation and counteract frequency variations. The effect of primary frequency control and self-regulating effect of load is often characterized by the *frequency control characteristic*, expressed in MW/Hz (also called Beta or frequency governing characteristic in North America). Second, *secondary frequency control* is a centralized automatic control that adjusts the active power production of generating units to restore the frequency and the interchanges with other systems to their target values following an imbalance. Last, *tertiary frequency control* refers to manual changes in the dispatching and commitment of generating units to restore primary and secondary reserves. Vocabulary related to frequency control differs from one system to another, but the three basic functions are most of the time the same. More information on the practical implementation of frequency control across various systems is given in [1]-[3].

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B. Synchronous Time

By counting the number of oscillations of the supplied alternative current (AC) and by knowing the nominal frequency of the network (e.g., 50 or 60 Hz), one can estimate the time, which is usually called *synchronous time*, *electrical time* or *electric clock time*, depending on the country considered. Of course, this time estimation relies on the initial time set locally (see section III.A).

In practice, some appliances use the synchronous time for their applications. For example, numerous mechanical clocks were historically using it. Today, some domestic appliances such as washing machines still make use of the synchronous time [4]. Section III.D discusses further the applications using the electrical time.

C. Time control

The *instantaneous* system frequency varies over time because of different events, such as the loss of a generating unit or the variation of load consumption. Frequency control rapidly brings the instantaneous frequency back to its target. However, the *average* system frequency usually deviates from its nominal value (e.g., 50 Hz or 60 Hz), which leads to a synchronous time drift. To bring the average system frequency (and thus the electrical time) back to its nominal value, the instantaneous system frequency has to be modified appropriately. Such a control is designated as *time control* within the Union for the Co-ordination of Transmission of Electricity (UCTE) [5]. The terms *time error correction* and *electric clock time control* are preferred in North America and Great Britain, respectively [7], [8]. Section II.A describes the actual operation of time control.

II. Technical Features of Time Control

A. Control of Synchronous Time Within the UCTE

The objective of time control is to monitor and to limit discrepancies observed between the synchronous time and the Co-ordinated Universal Time (CUT) within the synchronous area of the UCTE. The ETRANS control center at Laufenburg, Switzerland, is responsible for the calculation of

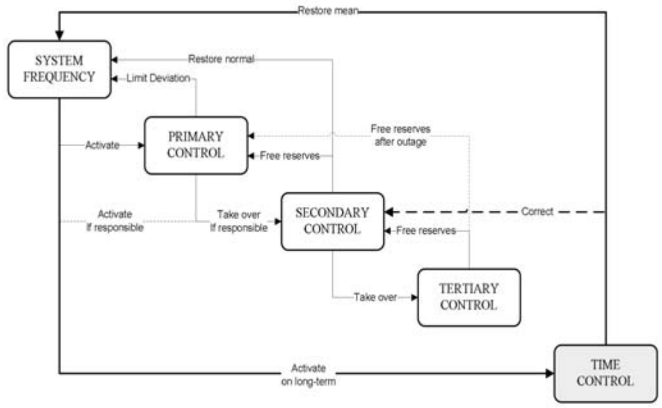

Fig. 1. Time control procedure within the UCTE [5]

the synchronous time and the organization of its correction. This center is thus called *time monitor*.

Since secondary frequency control maintains the system frequency at a given value, time control is simply performed by modifying the target frequency of secondary control f_t (see Fig. 1). Before 1998, the set value of the frequency was changed by ±50 mHz for a period of time that could vary (i.e., the duration could be different from 24 h) [9]. Since 1998, correction involves the setting of the set-point frequency for secondary control in each control area / block at 49.99 Hz or 50.01 Hz, depending on the correction direction, during a full day (i.e., from 00:00 to 24:00) [5]. The UCTE describes the following procedure [5]:

"The mean value of the system frequency shall be the nominal frequency value of 50 Hz […]. In practice, the deviation time should be within a range of ±30 seconds under normal conditions (an exceptional range of discrepancy of ±60 seconds is allowed)".

"The time deviation is calculated for 8 a.m each day at the ETRANS control center. The relevant time zone is the Central European Time (CET, equal to the Greenwich Mean Time plus one hour) with daylight saving (i.e., the time is changed twice a year). If the time deviation is lower than ±20 seconds, the frequency offset for time correction is set to zero. If the deviation is higher and synchronous time is behind the actual time, the offset is set to +10 mHz. Respectively, if the synchronous time is ahead, the offset is set to –10 mHz. Only under exceptional conditions (i.e., in case of a time discrepancy larger than ±60 seconds), offsets larger than 10 mHz for the time correction of the synchronous time may be used".

TABLE I
NUMBER OF DAYS WITH TIME CONTROL WITHIN THE UCTE

Year	Target frequency of secondary control (f_t)	Number of days
2005	49.99 Hz	95
	50.01 Hz	8
2006	49.99 Hz	79
	50.01 Hz	25
2007	49.99 Hz	54
	50.01 Hz	21

"The information for the time correction is forwarded towards all control areas / blocks of the UCTE synchronous area every day at 10 am by the time monitor for the following day. They forward this information towards their sub-control areas without delay. Each notice contains the time deviation, the time correction offset, the time correction procedure and the date and duration for the time correction. This notice is transmitted using secure and reliable electronic communication that allows a half-automated procedure. Time deviations and notifications on time error corrections are serialized by the time monitor on a monthly basis".

To give an idea, Table I provides the number of days between 2005 and 2007 during which time control was performed. 49.99 Hz is the most frequent frequency target different from 50.00 Hz. Therefore, the average frequency would have been higher than 50 Hz without time control. This characterizes a generation that tends to be larger than the consumption. This tendency may be explained by the incentives given by the balancing mechanisms to the balance responsible parties to be "long" rather than "short".

B. *Control of Synchronous Time in Other Systems*

Across the world, other systems have adopted strategies similar to the UCTE's. Table II provides the parameters chosen to perform time control during normal operation, where f_n and f_c are the nominal and correction frequencies, respectively. The new target frequency f_t is obtained by summing or subtracting f_c from f_n. Note that the differences that can be observed across systems underline the arbitrary aspect of time control standards.

In North America, another practice than modifying the secondary frequency control target frequency is possible. It consists in changing the net interchange schedule as a function of the frequency characteristic of the control area [7]. For example, if a –0.02-Hz correction has to be performed and if the frequency control characteristic is estimated at 10,000 MW/Hz, the net interchange schedule has to be changed by –200 MW.

C. *Impact of Time Control on Primary Frequency Control*

During the normal operation of a generating unit (e.g., when the unit is not islanded) and for a steady-state frequency deviation Δf from the nominal frequency f_n, a generator participating in primary control will change its generation by ΔP_G. The droop s_G of this generator, which is the gain of the feedback loop in the primary frequency controller, is then defined as in (1).

TABLE II
PARAMETERS OF TIME CONTROL ACROSS VARIOUS SYSTEMS DURING NORMAL OPERATION

System	Nominal freq. f_n	Allowed range	Correction freq. f_c	Correction duration	Ref.
UCTE	50 Hz	[–30 s; +30 s]	0.01 Hz	1 day	[5]
GB	50 Hz	[-10 s; +10 s]	0.05 Hz	¼ h	[8]
East NA	60 Hz	[-10 s; +10 s]	0.02 Hz	½ h	[7]
West NA	60 Hz	[-2 s; +2 s]	0.02 Hz	½ h	[7]
ERCOT	60 Hz	[-3 s; +3 s]	0.02 Hz	½ h	[7]

GB: Great Britain; NA: North America

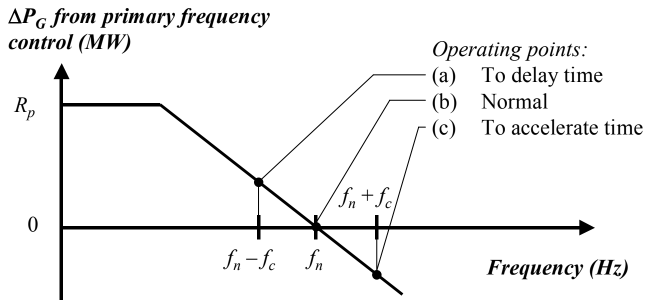

Fig. 2. Evolution of the available primary frequency control reserve as a function of the system frequency

$$s_G = -\frac{\Delta f \,/\, f_n}{\Delta P_G \,/\, P_n} \qquad (1)$$

where P_n is the nominal generator output power.

Primary frequency control is thus activated when the system frequency is different from its nominal value (e.g., 50 Hz or 60 Hz). Therefore, the primary frequency control reserve is lower than forecasted in case of a target frequency below its nominal value, in proportion to the speed droop of the generating unit (see Fig. 2). Conversely, the primary reserve is higher in case of a target frequency greater than the nominal value.

For example, the share of consumed positive primary reserve of a generating unit during a 49.99-Hz time correction is given by:

$$\frac{\Delta P_G}{R_p} = \frac{0.01 \cdot P_n}{s_G \cdot 50 \cdot R_p} \qquad (2)$$

where R_p is the positive primary reserve of the generating unit, which corresponds to the maximal available ΔP_G (see Fig. 2). Hence, a French 1300-MW nuclear unit providing 26 MW of positive primary frequency control reserve with a droop at 4 % deploys 25 % of its reserve during a 49.99-Hz time correction (supposing that the frequency measurement is perfectly accurate and that the controller insensitivity is lower than ±10 mHz).

Note that before 1998, the nominal frequencies of the UCTE generating units were supposed to be adjusted in order to avoid the usage of the primary frequency control reserve. However, this arrangement was complex. In practice, only German and French nuclear power plants were performing this change with the help of a partly automatic adjustment of the turbine governor set point. All the other generators operating under primary control were not adjusting the reference value of their frequency governors [9]. Therefore, the primary reserve provided by these latter units was used continuously. Hence, sufficient primary frequency control reserves were not available in case of contingencies such as the loss of a generating unit.

III. Five Reasons to Abandon Time Control

A. Time Control does not Mean a Unique Time

One often argues that time control guarantees that every clocks show the same time (which would have been useful to synchronize trains across a country, for example). However, frequency acts only as a ruler. To show a unique time, all the clocks have to be precisely set to the same time (i.e., the local reference should be the same), which is difficult to achieve without dedicated information infrastructure. In addition, devices are sometimes disconnected from the network or connected to an islanded network. For example, European devices have followed three different electrical times during the 4th November 2006 incident, which split Continental Europe into three different parts, as shown in Fig. 3 [6]. Even if the UCTE procedure stipulates that "before re-connecting asynchronous areas of the UCTE network, the differences of time deviations between the different synchronous areas need to be in target range. The smaller grid area being reconnected needs to limit this difference and to take over the synchronous time from the larger grid area once the re-connection is in operation" [5], time control was probably of little concern for the TSOs during the event. Therefore, the European clocks using the electrical time have been certainly showing different times since this incident.

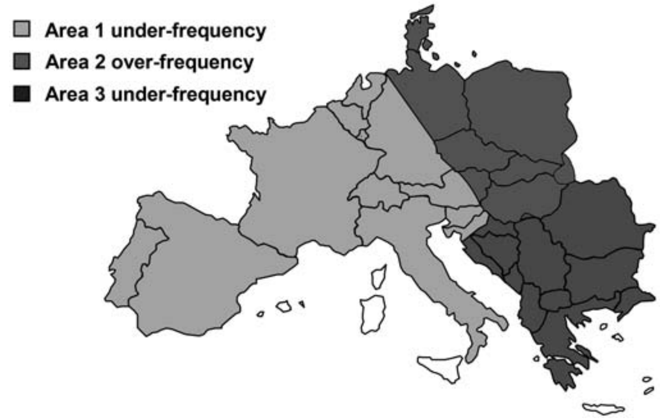

Fig. 3. UCTE splitting during the November 2006 incident [6]

Since the three parts have been reconnected, re-adapting the electrical time in the various parts of the synchronous network has been impossible because the frequency of a synchronous system is shared by all the users. Therefore, modifying the frequency set points of the different secondary frequency controls is useless. Moreover, such a procedure would threaten the security, as shown in section III.C.

B. An Accurate Synchronous Time does not Bring Cross-Border Exchanges Back to Their Values

Primary frequency control is shared by the whole synchronous area. Therefore, unscheduled power flows appear at the borders of the control areas in case of frequency deviations. It is often argued that time control is a mean to compensate in nature the unscheduled cross-border exchanges following the usage of primary frequency control. This assumption is fallacious for at least three reasons.

First, the unscheduled exchanges cannot be exactly compensated by time control. In fact, the frequency characteristic of a power system (in MW/Hz) varies over time as a function of the number and types of synchronized generating units, the load level or the types of connected loads. Therefore, the power deviation (in MW) corresponding to a given frequency deviation (in Hz) varies with time. Hence, the average unscheduled energy (in MWh) is not as a direct function of the average frequency deviation. To illustrate our purpose, let us suppose that the average system frequency and the system frequency characteristic were respectively equal to 49.99 Hz and 20,000 MW/Hz during one day (note that a frequency characteristic constant over one day does not happen in the actual operation of the system). Therefore, to bring the average frequency back to its nominal value, the TSO decided to keep the average frequency at 50.01 Hz the next day, during which the system frequency characteristic was equal to 19,000 MW/Hz. Hence, the deviation from the nominal frequency during the two days produced an average of 240 MWh of unscheduled flows (20,000 MW/Hz times 0.01 Hz times 24 h minus 19,000 MW/Hz times 0.01 Hz times 24 h), while the average frequency during these two days was equal to 50.00 Hz.

Second, usually only one control area creates the time unbalance (e.g., by losing a generating unit). On the other hand, all the control areas participate in time control by maintaining a frequency different from the nominal value. In other words, with the time control method, the unscheduled generation is compensated by all the control areas across the synchronous system, whereas only one area should actually deploy this power. Furthermore, this generation compensation does not guarantee that the power flows are appropriately offset for each interconnection. A more appropriate way to compensate in nature the unscheduled flows would be to modify the exchange schedules according to the unscheduled flows created by each zone. However, such an arrangement would not be very practical.

Third, time control may worsen the exchanges between two areas if they do not use the same target frequencies following an operational problem. For instance, area 1 may want to operate secondary frequency control with a set point at 49.99 Hz, whereas the frequency target of area 2 is 50.00 Hz. This case can easily happen in actual operation. For example, UCTE states that "in case the time deviation and correction notice is missing for a TSO, the TSO applies the nominal frequency of 50 Hz as frequency set-point value for secondary control until it receives the outstanding notice" [5]. The problem brought by different target frequencies is explained in the following section.

Last, time control cannot guarantee a "fair compensation" in nature. In fact, the compensation of the unscheduled flows should be performed during similar situations, e.g., when the value of electricity is similar during the unscheduled flows and the compensation. However, time control cannot bring such guarantees.

C. *Time Control Threatens System Security*

Another popular argument in favor of time control is that an accurate synchronous time improves system security. Such an argument is simply erroneous. First, the authors are not aware of any argument that advocates for an increased security with the help of time control.

Second, by setting the system frequency at a different value than the one implemented in the governors of generating units, time control reduces the available primary frequency control reserves, as shown in section II.C. More precisely, either the positive reserve is increased while the negative one is reduced (operating point C in Fig. 2), or vice versa (operating point A). Therefore, it is necessary that TSOs modify their primary reserve requirements in order to compensate this loss of reserve. However, such a policy is not widespread in Europe. In theory, this reserve modulation should not be constant as it depends on the droops of the generators participating in primary frequency control during time control. Therefore, if time control is maintained, a minimalist fair policy could be to define the primary reserve modulation according to the minimum UCTE frequency characteristic without considering the self-regulating effect of load, i.e., 15,000 MW/Hz [5]. Therefore, the positive primary frequency control reserve modulation would be +150 MW for the whole UCTE synchronous zone during 49.99-Hz days and –150 MW during 50.01-Hz days (and vice versa for the negative primary frequency control reserve). This reserve modulation could then be shared amongst control areas according to their participation in the UCTE primary reserve. The security of the system would thus be ensured, while the extra reserve cost (and potential savings) would be shared.

Third, as mentioned in section III.B, TSOs may have different target frequencies at the same time following an inappropriate operation. Such a situation may create power oscillations. For instance, Table III shows the secondary control powers of two control areas with target frequencies set to 49.99 Hz and 50.00 Hz, respectively, as a function of the instantaneous system frequency. An up arrow indicates that the secondary frequency control tends to increase its power, while a down arrow shows a tendency to decrease secondary control power (in practice, the actual secondary frequency control power depends also on the interchange schedule). With a frequency between 49.99 and 50.00 Hz, the two areas cannot agree on the best frequency to consider. Therefore, depending on the parameters of the respective secondary controllers, the frequency will fluctuate between 49.99 and 50.00 Hz.

Considering these arguments, it is clear that *controlling* the synchronous time does not improve system security. However, *monitoring* helps to assess the quality of frequency control and hence is useful to improve frequency control over the long run. Therefore, time control could be abandoned,

TABLE III
CONSEQUENCES OF DIFFERENT TARGET FREQUENCIES ON THE SECONDARY FREQUENCY CONTROL POWER OF CONTROL AREAS

System frequency	Control area 1 (target at 49.99 Hz)	Control area 2 (target at 50.00 Hz)
< 49.99 Hz	↗	↗
= 49.99 Hz	→	↗
> 49.99 Hz and < 50.00 Hz	↘	↗
= 50.00 Hz	↘	→
> 50.00 Hz	↘	↘

while keeping the synchronous time monitoring.

D. Electrical Devices Currently do not Need Time Control

Before using the electrical time as time reference, designers have to keep in mind some drawbacks due to the time control implementation. First, the synchronous time is not adjusted in real-time, but by periods (see Table II). Therefore, only devices operating longer than the control period duration are concerned by time control.

Second, despite time control, the synchronous time deviates from the reference time by several seconds (see Table II). Therefore, the usage of the electrical time is limited to devices requiring a poor time precision. In fact, processes that need an accurate time can use other technologies, such as the Network Time Protocol (NTP) for devices connected to a network, or the Global Positioning System (GPS) for any system with an outdoor access.

In regards of these two drawbacks, designers should avoid the use of the electrical time for critical devices. In practice, the authors did not find any documents related to crucial electrical devices using the synchronous time (only a few domestic applications were found, e.g., [4]). However, two important applications that potentially use the electrical time have been identified, but no document has been found. First, some old medium- and low- voltage electrical meters in Switzerland are deemed to rely on the average frequency to select the tariff to apply. The authors do not know how the time of these meters is set after an electrical shut down, which usually happens once a while (e.g., the commitment in France is to cut power less than 6 hours over one year [10]). If the time-setting procedure exists, the same corrective measure could be adopted in case of the abandon of time control. Furthermore, this system is constraining, because the daylight saving is difficult to implement with sole electromechanical devices. In other countries such as France, a higher-frequency signal (e.g., 175 Hz) is sent over the lines to give the meters the tariff-swapping instruction. A second application that is deemed to use the electrical time is the protection of some bank safes in Japan. However, no further information on this practice was found by the authors. Moreover, if this technology exists, it is not proven that it is widespread in the world. In conclusion, public information on these important applications should be increased in order to take the appropriate decision relative to time control.

For non-critical devices, the two drawbacks of the time control design (i.e., no correction during given periods and poor accuracy) are just slightly increased without time control. In fact, the potential time deviation over one year without time control would be limited, as shown in Table IV. This table gives the deviation that would have resulted in the absence of time control, where the values have been obtained from Table I. Because of a good frequency control, the time deviation was less than 10 minutes in 2007. Furthermore, because of the daylight time saving procedure, Europeans set their clocks twice a year. Therefore, the actual deviation of the devices would have been limited to around 3 minutes in 2007. Such a deviation is probably acceptable for domestic appliances like alarm clocks or washing machines.

In conclusion, the importance of time control for critical devices has to be proven. Furthermore, it is dubious that devices requiring a poor time precision cannot withstand time deviations lasting for several minutes.

E. Time Control Costs Money

The previous sections have shown that time control is low value-added. Furthermore, time control incurs several costs to the participants. First, the TSO's operation costs are increased because the system operation is more complex, as it needs appropriate workforce and equipment to perform this control. For example, within the UCTE, the main center calculates the frequency target. Then, it sends the target to around 30 TSOs of the synchronous area. Lastly, the TSOs have to update the target frequencies of their secondary frequency controls. Such a procedure obviously needs people, software and information infrastructure to be implemented.

Second, TSOs may need to reserve extra capacity to compensate the usage of primary frequency control reserve, as explained in section II.C (e.g., the positive primary frequency control reserve has to be increased or decreased if the target frequency is equal to 49.99 Hz or 50.01 Hz, respectively). As the number of days at 49.99 Hz is larger than the number of days at 50.01 Hz (see section II.A), and because the incremental cost of reserve (e.g., in €/MW) is higher than the incremental saving, such a procedure costs money [3].

Third, as shown in section III.C, time control may weaken the security, which has a cost over the long run. This cost is hard to quantify but is high (e.g., see [11] for the Norwegian interruption costs).

Therefore, the cost incurred by time control should be reduced if possible. The simplest solution is to abandon time control. If this is not possible, the accuracy of the control could be decreased (e.g., set to ±5 minutes), which would lead to less days with a target frequency different from its nominal value. Second, the system frequency characteristic provided by generating units could be estimated half-hourly and thus the primary frequency control reserve could be adapted accordingly, instead of keeping a constant requirement during the whole year (e.g., 3,000 MW within the UCTE [5]). Such a solution would guarantee the system security while minimizing the reserve cost. However, this solution would increase the operation costs due to a more complex operation.

IV. Conclusion

Time control maintains the average electrical frequency to its nominal value over the long run. This paper highlights five

TABLE IV
POTENTIAL SYNCHRONOUS TIME DEVIATION WITHOUT TIME CONTROL OVER ONE YEAR WITHIN THE UCTE

Year	Over the year
2005	00:25:03
2006	00:15:33
2007	00:09:30

reasons to abandon time control: (a) time control threatens system security by using primary frequency control reserves; (b) electrical devices currently using time control do not need a great accuracy. In fact, the accuracy provided by the electrical supply without time control would probably be sufficient. On the other hand, devices that need a great precision can benefit of various alternative technologies; (c) a unique synchronous time across the whole system actually does not exist, so this argument should not be used to justify time control; (d) time control does not bring back the cross-border exchanges to their contractual values, so this argument should not be used either; (e) time control costs money for both TSOs and users whereas no particular value has been identified. In fact, time control needs appropriate workforce and infrastructure. Moreover, the increased demand for reserves because of time control increases operation costs, while no reserve demand variation increases the probability of load shedding.

In regards of the cost-benefit analysis performed in this paper, it appears that time control should be abandoned. To do so, information on the procedure should be sent to the electrical system users. If no user raises serious concerns on this procedure, a test period of one year could be engaged, followed by a return on experience. Note that the current procedures to set the time of devices using the synchronous time could be called upon regularly if necessary. Last, a final decision could be taken. Another solution would be to adopt a time control with a precision of several minutes (e.g., ±5 minutes) instead of tens of seconds. Such a procedure would reduce the time control cost while keeping an acceptable accuracy. The feedback from parts of the world that potentially do not perform time control would also be very useful to the community.

In any cases, the synchronous time deviation should still be monitored, as it serves as a good indicator to evaluate the quality of frequency control.

V. Acknowledgment

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