ABSOLUTE TIME SYNCHRONISM
BETWEEN POWER SYSTEM FAULT RECORDERS
AND SEQUENCE OF EVENTS RECORDERS

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This paper addresses the problem of maintaining absolute real time synchronism between many remote transmission substation locations containing fault and sequence of events recording equipment. Several methods are described which have been under field evaluation for over five years and are in current use at Georgia Power Company.

These methods include: (1) utilizing a master time source for transmission via microwave of a time code data stream (IRIG-B) to selected remote locations. (2) utilizing the National Bureau of Standards 60 KHz transmission (WWVB) from Ft. Collins, Colorado to provide time data via commercial WWVB receivers. (3) utilizing the GOES satellite transmission to synchronize time data at selected locations via commercial GOES receivers.

Advantages and disadvantages of each method are presented along with field data to support these methods.

Synchronism to absolute real time provides a common time base for analyzing system faults and disturbances recorded at many remote locations over a large geographical area with typically one millisecond resolution. This approach also allows the user to compare events and fault data between various utilities where reference is made to absolute real time.

INTRODUCTION

Since the first fault and event recording systems were placed in service years ago, some method of "time tagging" the recorded data was provided. These methods have included a physical stamping of time of day on oscillographic records, flash tube photographic techniques, L.E.D. strobe techniques, and recording time data on magnetic tape.

With the advent of higher transmission line voltages, larger capacity generating plants, and more sophisticated high speed relaying systems, an increasing burden was placed on the fault data equipment to be able to properly resolve events and disturbances over a large area.

The increasing requirement to be able to analyze data on a real time basis from several locations for any one disturbance has led to the investigation of improved methods of time tagging the recorded data.

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This paper will address the methods investigated and used by Georgia Power Company to significantly improve the time synchronism between various locations. The systems in use have improved the synchronism accuracy by three magnitudes over previous methods. These improvements have greatly enhanced the ability to properly analyze, document, and take corrective action on problems occurring with power system transmission equipment and protective relaying systems.

BACKGROUND

In any fault recording system, some method must be used to identify each record so it can be related to system conditions and aid in documenting and analyzing various events and disturbances. Usually, time of year information (DAYS, HRS, MINS, SECS) is recorded along with power system data at the time of fault occurrence. This time of year data can have a resolution of one second without too much difficulty. Usually these clocks providing the time data are synchronized to the 60 Hz line frequency and contain some type of back up oscillator to insure continued operation during AC power outages. While the 60 Hz line method can provide very good long term stability (months), its short term stability (minutes-hours) is grossly inadequate to achieve one millisecond accuracy between several recorders. Even if the above problem is not considered, all too often these recorder clocks (fault recorder and sequence of events recorder) are set by personnel using local station clocks, wristwatches, or pure guesswork as a reference. While the individual recorder clocks can then maintain a fairly accurate elapsed time over the long term, the accuracy between different clocks and any relationship to absolute real time can be horrendous at best.

Continuous monitoring thirty-two channel magnetic tape fault recorders provide the majority of all fault data for Georgia Power. With over seventy of these systems in service, a tremendous amount of pre-fault, fault, and post-fault data is available for analysis on any one given disturbance. Additionally, over one hundred sequence of events recorders are located throughout the power system and also provide data during disturbances.

Originally the above recorders were synchronized to the 60 Hz line frequency. The time resolution was very poor. Eventually electronic time code generators with digital read-outs and improved code outputs were installed and resolution improved by a factor of six. However, we were still at the mercy of local clocks, wristwatches, and guesswork.

As additional critical EHV substations and generating plants were placed in service, more stringent requirements were necessary to properly document faults, outages, and disturbances.

Companies within the Southern Company (Alabama Power, Georgia Power, Gulf Power, and Mississippi Power) were in need of a system for synchronizing clocks on fault recording equipment to some master source.

IRIG-B SYSTEMS

Several possibilities were investigated with the final determination made to use equipment located at Southern Company Services in Birmingham, Alabama to generate the master time signals. Since the Southern Company Communications and Data Center is at this location and very extensive company microwave and communications equipment is in place to all sister operating companies, this made an ideal location from which to transmit time code data to the various company headquarters. Once this time code was transmitted to the Georgia Power General Office in Atlanta, it could be further routed over company owned microwave facilities to individual substations and fault recording equipment.

The time code format to be used was the Inter-Range Instrumentation Group Type B (IRIG-B) and consisted of a 1000 Hz carrier that was amplitude modulated with the time code data in BCD format. This format has adequate resolution (1 millisecond), transmission capabilities that fit available data grade channels, and can easily be recorded on magnetic tape. Refer to Figure 1 in the appendix for an example of the IRIG-B format. Time information is BCD coded by use of the modulated carrier with two cycles of modulated data (large cycles) representing an "0" bit and five cycles representing a "1" bit. Frame position identifiers are shown as eight cycles of modulation. This format is one second long and is a continuous time code updated every second. Complete time of year data is contained in this time code from day of year through seconds with "time of occurrence" being resolved to within one millisecond. Additional data bits for any special needs or control functions are also provided in the time code and may be used as necessary. The basic idea behind the master time synchronizing project was to have all fault data clocks on the same time base and have that time base referenced to absolute real time. If only relative time is important, savings can be experienced and a much simpler system installed. However, be aware that the ability to use other time sources such as WWV, WWVB, and the GOES satellite in conjunction with the relative time system would not be feasible.

The system currently being used at the master station consists of the following equipment: one primary Cesium atomic time standard, one secondary Rubidium atomic time standard, one WWV receiver, one Loran-c receiver, and three independent digital clocks feeding a majority gate arrangement to insure agreement between standards. Sufficient power supply redundancy is provided to insure continuous operation.

Since all time transmitted from the master is tracable and synchronized to the National Bureau of Standards, any WWV, WWVB, or GOES equipment may also be used along with the IRIG-B data with accuracy synchronism possible. However, the time code format and sequence of events recorder scan time limits the practical resolution to one millisecond.

Certain locations within our system are not served by company owned microwave facilities and leased circuits are not a viable option. In these cases, WWVB or GOES Satellite receivers are being used to achieve synchronism to the master clock. Additional data will be provided later for information on these auxiliary devices.

Data from the master clock is transmitted via numerous microwave sites to the Georgia Power General Office communications center. Here the signal is rerouted and split as necessary for retransmittal to the many remote locations throughout the state. Various synchronized time code generators are used to decode the incoming IRIG-B, to adjust for propagation delay, display and buffer the data for recording on the magnetic tape during fault conditions. This equipment has proven to be immune to noise, switching transients, and signal polarity reversals while providing reliable operation.

No matter what type of equipment is used, if a real time system is desired, this equipment must update the display and all outputs at the beginning of the second rather than at the end. Since it would take a second to read the incoming data, the outputs would be in error by this time. With accuracy and resolution of 1 millisecond desired, attention must be given to the propagation delay times from the master to each remote.

A portable Rubidium atomic time standard is used to measure all propagation delay times. This standard is periodically carried to the Birmingham master clock for resynchronism. Typical drifts have been on the order of 2 milliseconds over a twelve month period. Once the portable clock has been synchronized to the master, the portable is transported to the remote location and the signal delay is observed on a scope and measured on a counter with time interval measurement capability. Within Georgia, propagation delays range from 3.75 milliseconds to 7.70 milliseconds from the Birmingham master.

Attention must also be given to observing proper scope triggering techniques whether on the leading or trailing edge of the IPPS signal in the various equipment to insure accurate measurements. The propagation delay offset-switches in the time code generator (TCG) can then be adjusted so the output of the TCG exactly matches the time of the master. If a portable standard is not available, various loopback/computational methods can be used to derive propagation delay times.

This master time is also used to synchronize the substation sequence of events recorder (SER) clock. The best time resolution of the SER is 1 millisecond, therefore, it is not very critical to maintain real time accuracy better than that. Experience indicates that time synchronism of both the SER and the fault recorder to be of great benefit during fault conditions. Times can be compared from both ends of the faulted line. Sequential tripping and associated reclosing can now be observed without the previous guesswork of what happened first. In the past, many events happened but it was always practically impossible to correlate relay trip outputs and breaker operations from several remote SER's. Many times, operations would occur when faults were not involved and the SER was the sole source of data from each end of the line. With time synchronism between these SER's, data can be compared on a real time basis. Experience has shown over the years that it is becoming more and more critical to install not only fault recording systems, but also sequence of events recording systems to gather all possible data for analysis of power system operating conditions.

The necessary synchronizing circuits to interface the fault recorder clock to the SER clock are usually added as a field modification and may consist of sync pulses of IPPS, and/or IPPH depending upon the equipment involved. Certain SER's are also capable of reading parallel BCD time code and applying the decoded time directly to the internal clock for automatic reading and updating. This feature greatly enhances and simplifies the automatic synchronism of SER systems to absolute real time. Recent product enhancements now allow inclusion of a plug-in time code translator directly into the SER mainframe. Parallel BCD inputs are no longer required since the SER translator accepts the raw IRIG-B time code directly via coax from the communications channel or satellite receiver. Propagation delay adjustments are provided on the internal translator.

Most SER systems employ some type of internal digital filtering to eliminate contact bounce. This procedure can introduce errors where absolute real time recordings are required. In some cases, these offsets are corrected in software. Many other types require the adjustment of at least four milliseconds to the printed time to allow real time comparisons to the fault recorder times.Another method that may be used to record time code does not involve the use of a TCG at all. The IRIG-B signal as received at each remote location may be applied directly to the fault recorder channel input. While an obvious advantage is saving the cost of a TCG, several disadvantages are also realized. One, propagation delay times cannot be easily and automatically accounted for if that is desired. Two, no on-site display is available to indicate the presence of time code data and show the time of year information. Three, if the master fails or any communication channel fails, there is no time code data available for recording and usually no way of knowing the channel is inoperative.

Since the IRIG-B signal drives the TCG input, and the TCG output drives the recorder, all of the above problems are solved. Even if the input signal from the master clock fails, the TCG continues to function as a stand alone time code generator. As soon as the master clock signal is received again. the TCG will automatically correct any drift and continually update time once more. An internal oven controlled oscillator in the TCG then serves as the time base. Its stability is approximately 1 part x 10^{-9}/day. During propagation delay measurements, using the atomic standard, this internal oscillator is fine-tuned for minimum drift.

While requiring extensive communications circuits, the IRIG-B system has proven to be extremely reliable.

The desired end results and user needs will determine the most feasible approach for recording the time information.

The user must also be aware of an operating problem when using a master clock system with magnetic tape or any other device having synchronous motors as a driving medium.

If these synchronous motors are driven from an inverter source and the inverters throughout the system are not synchronized to each other, the recorded oscillographic data cannot easily be physically aligned between machines. The recorded times will be correct but will not necessarily match if overlayed. The use of stabilized and synchronous inverters would eliminate this problem. Using the IRIG-B carrier to sync the inverters would be one method. Consideration should also be given to the playback machine itself if extreme accuracy and trace alignment is a rigid requirement.

While this shortcoming exists, it usually does not present a problem unless several oscillograms are overlayed on each other for comparisons. In these cases, times must be identified individually on each oscillogram for comparisons.

Tape speed differences can be observed that are translated into distances on the oscillogram on the order of .25 to .50 MM (.01 to .02 in) for a record 30 cm (12 in) in length.

WWVB SYSTEMS

Several locations in this system are not served by company owned microwave sites, yet it is desired to have the fault and event recording equipment at these locations synchronized to the master clock. Cost estimates and reliability evaluations have resulted in considering methods other than leased circuits.

Initially, WWVB receivers were installed at certain 500KV substations to synchronize the local TCG's. While the equipment purchased has proven to be reliable, several operational problems have been experienced. One of the major problems is the location of the WWVB recorders approximately 2250 km (1400 mi) from the NBS transmitter in Ft. Collins, Colorado. Sites within a few hundred kilometers of the transmitter may experience signal strengths of 2500 microvolts/meter while those in Georgia usually receive 100 microvolts/meter or less. If the user is only interested in measuring frequency, using the WWVB signal as the reference, no major problems are encountered even at distant locations. However, complete phase lock and accurate time reception are desired 100% of the time. Data has been gathered over a period of years on the feasibility of extensive use of WWVB equipment. This data has shown predictable and expected signal dropouts usually twice a day at times of local sunrise and sunset. This phenomena is caused by the "dinural shift" and is caused by the day/night line progressing between the transmitter and receiver. Usually this loss of signal lasts for less than one hour and its occurrence varies as the time of local sunrise and sunset varies every day. Realize that even though the receiver loses phase lock it continues to function on its back-up internal oscillator but a drift from real time is experienced. This drift rate has been measured to be approximately 10 milliseconds per hour after final oscillator adjustments have been made.

Another problem in using WWVB timing has been noticed during times of severe weather disturbances. Thunderstorm activity has a detrimental effect in allowing noise cancellation on the received signal with the approaching storms. Since numerous thunderstorms and related bad weather during the spring and summer months are a common occurrence, many signal dropouts have been recorded. Unfortunately, most faults also occur during these times. A true synchronized time system for these WWVB installations as related to our IRIG-B sites does not exist during these storm periods. The IRIG-B sites are in sync over 99.9% of the time day in and day out. The WWVB sites approach 85% signal lock at their best. Again, this is mainly because of our distant location from the transmitter and the location of the receiving equipment. An electric transmission substation has not proved to be the best environment for receiving the 60 KHz WWVB signal for time code reception. Excessive corona from switches and various buswork has made reception extremely difficult at several locations. The physical arrangement of the substation, practical limits of antenna height, and distance from the receiver was also a limiting factor.

During laboratory tests away from the substations this equipment performed as expected. In all cases, the antenna consisted of an active system using a 30 cm (12 in) ferrite rod typically elevated approximately 15 feet.

All WWVB installations have been removed from service and no others have been scheduled for future additions due to the above mentioned problems.

Propagation delay measurements are made at these WWVB sites just as they are at the IRIG-B sites. Using the portable atomic clock the IPPS received via the WWVB receiver can be exactly aligned with the IPPS from the master clock in Birmingham thereby maintaining true real time sync between the WWVB receiver and the master clock.

WWV equipment has not been considered for use since its code format does not provide a continuous time code broadcast but only 1 PPS ticks. This prevents the automatic clock setting capability from being used.

GOES SATELLITE SYSTEMS

Several years ago commercial equipment became available for receiving and decoding the time code data from the GOES satellite system. These are the Geostationary Operational Environmental Satellites placed in synchronous orbit approximately 22,300 miles above the equator. There are three working satellites in orbit. The East Satellite at 75 degrees West Longitude, the West Satellite at 135 degrees West Longitude and a spare 105 degrees West. Excellent coverage is obtained over all of North and South America with these satellites. Experiments were conducted with both the East and West Satellites with reliable synchronism obtained from both. However in Georgia, the East Satellite was used for normal operations mainly because of its higher angle above the horizon (52 degrees vs 24 degrees) and its operating frequency.

Commercial satellite receivers were under evaluation for approximately four years and presently twelve different sites are in service. This equipment is being monitored by sequence of events recorders to determine the time and duration of signal outages. Basically, field data indicates GOES provides much more reliable operation (95%) than with the WWVB system. The satellite signal reception is not susceptible to the "dinural effect" and thus far thunderstorm activity has not had a detrimental effect on the received signal. One location has the antenna "looking" through a 230KV bus structure with significant corona and no detrimental effects have been seen on the received signal. A WWVB receiver would not work at all at this site. Even though we have experienced no satellite data problems with radio interference, the user should be aware the operating frequency is approximately 468 MHz. This is the spectrum used by certain "land-mobile" services.

A few equipment problems have been experienced but the biggest reason for signal disturbances has been due to the spring and autumn solar eclipse period. These eclipses can last up to approximately one hour per day at approximate local midnight from March 1 to April 15 and again from September 1 to October 15. Usually the spare satellite is used during this time to insure continuous operation but the predetermined propagation delay times on each receiver are then in error. This could cause a difference of up to 20 milliseconds between the GOES receiver and our master clock. Adjustment of the propagation delay or switching to the West Satellite during these times would eliminate these problems. Since the time transmitted via the satellites is maintained to NBS time by time standards at Wallops Island, Virginia, direct comparison to our IRIG-B master source can be maintained.

Receivers are currently available, and we presently have two systems in service, that actively track each satellite and automatically and constantly adjust the propagation delay times to insure ± 100 microsecond accuracy. When user longitude and latitude are entered into the clock even switching between satellites causes no appreciable time error to occur.

To insure all time is synchronized, the portable atomic clock is transported to each GOES receiver. The time delay measured and adjusted on each receiver to bring all IPPS signals together. After analyzing oscillograms from IRIG and GOES receivers for the same fault, very good results within the desired 1 millisecond requirement are obtained. While evaluations are still under way, it appears that the satellite receivers will be a cost effective alternative to leased circuits. This system could also provide excellent synchronizing capabilities for certain individual remotely located sequence of events recorders. By merely pointing the antenna at the satellite and connecting the receiver output to the event recorder, accurately synchronized time can be automatically maintained. The antenna for this system is approximately 30 cm (12 in) square containing an active microstrip antenna. Field tests initially indicated one disadvantage was the requirement to mount the active antenna outside the control house where it could be subjected to severe environmental changes. Recent product improvements have significantly improved performance in this regard and, if necessary, the active portion of the antenna may be installed inside the control house.

FIELD EXPERIENCE AND APPLICATIONS

Several techniques may be employed to record the time code data on the magnetic tape. Usually this data is recorded only for approximately ten seconds when the fault or disturbance occurs. This data can be in the form of a DC level shift TTL output voltage that would appear as a square wave pulse train coded in BCD format. Resolution can be interpolated to within one millisecond.

We have chosen to use the true 1 KHZ amplitude modulated IRIG-B signal from the TCG rather than the DC level shift code. One advantage is the one millisecond time base is much easier to resolve since each cycle of the carrier represents one millisecond. By using this format, a time code reader can be used on the tape playback system to automatically display the recorded time data on a digital clock. Instead of having to manually decode the time data during playback, the code reader can be used to do this automatically. This saves considerable time and oscillograph paper since the desired fault can be located before any paper has to be processed. With the costs of direct print paper increasing, it doesn't take long in saved time and paper to pay for the reader. The particular commercial model has the capability of not only reading the recorded time, but also allows one to dial in a selected time and have the search unit control the tape deck until that time is located.

As previously mentioned, the time code data is usually recorded for only approximately ten seconds. We have chosen to lengthen this to sixty seconds. Two advantages are realized. One, the longer time frame makes locating the fault information much easier. Two, the longer time frame is necessary for proper time references during system disturbances and faults involving generators.

At certain installations even sixty seconds is not adequate for the type data we desire to analyze. For these applications, we dedicate an entirely separate channel for recording continuous time code. This method better utilizes the continuous data recording available on the fault recorder. Every cycle of recorded data can be identified with a time resolution of one millisecond and also be identified relative to real time. If we desire to locate data that occurred, for example, 17 minutes 28 seconds prior to some event or fault, that can be easily and rapidly done with the combination of continuous time code and time code reader. It may be then determined that the preceding event really occurred at 17 minutes 28 seconds and 373 milliseconds in absolute real time. Data from several other recorders may also be compared to each other since all clocks are synchronized to a master source. This allows viewing vast amounts of prefault as well as post fault data from several recorders and identifying each cycle on each recorder with a real time tag having one millisecond resolution. Initiating events, and "cause and effect" type phenomena can be easily resolved over a large geographical area.

In one case we were able to determine that the initiating event for a serious generator problem was recorded some two minutes prior to the actual trip. Two isolated recorders over 200 km (125 mi) apart had prefault data that could be viewed on a real time basis and allowed the true initiating events to be identified.

Many times distant problems have occurred before, during, and after system faults. Previously, trying to relate these problems to the system faults was difficult if not impossible to do. Now with everything time synchronized, all recorded data is easily compared in real time.

Often problems at first were thought to occur simultaneously. In one instance after reviewing real times, it was determined this was not the case. Two different problems occurring 12 milliseconds apart had occurred. A more direct troubleshooting approach was then initiated and the problem was quickly solved. One must also realize we are considering data from the sequence of events recorder as well as the fault recorder at locations remote from the fault.

There have also been cases where data revealed the problems actually did occur simultaneously during a fault, reclose, etc. Previously this may have gone undetected but now corrective action can be taken before additional problems cause outages, equipment failures, or unnecessary downtimes.

Presently automatic reader high speed search capabilities on the fault recorder are not possible since the time code data is recorded using the FM saturation recording technique. Once the recorder is modified to allow time code recording using the direct analog method, this problem will be eliminated. Then the user can fully utilize the reader/search unit to automatically search the tape at high speed looking for some specific predetermined time and locate that exact spot in time. The second channel previously used for continuous time code would not be necessary.

When time code data is decoded to retrieve the time of year information, the question that always arises is, "Was the time code generator synchronized to the master clock at the time of the disturbance or fault?". This information is vital if many recorders are to be compared with any degree of accuracy. If the recorder clock was not in synchronism, the internal drift could cause a minimum of several milliseconds error.

Modifications have been completed to allow a previously unused control bit in the time code format to indicate if the remote clock was synchronized to the master. This "sync bit" is easily readable on the oscillogram and is also displayed on the time code reader. One can tell at a glance if the recorded data was synchronized to the master. Knowing this, all data can be compared with confidence. The presence or absence of the "sync bit" is also monitored on the substation sequence of events recorder to provide additional data on channel reliability.

ADDITIONAL DEVELOPMENTS

When synchronizing the fault recorder TCG with the SER clock, the ideal method would allows automatic time reading by the SER.

The parallel BCD outputs from the TCG can be used as inputs to the SER to accomplish this task. Certainly this method is far superior to previous IPPS or IPPH sync circuits. However, since the fault recorder TCG may be a considerable distance from the SER, routing the multi-pair cable with BCD TTL data through various cable trays can cause noise problems on the inputs. Additionally, the expense of fabricating the cable can be significant.

We are now using a small internal IRIG-B receiver that plugs directly into the SER. This permits automatic time setting and updating by providing the IRIG-B signal on a coax cable directly to the SER. This integral receiver has provisions for propagation delay adjustments and a stable oscillator to insure less than 2 ms drift per hour when no input is present.

As more SER's are added to the power system, its becoming important to synchronize the "stand-alone" SER where a fault recorder TCG may not be available. Rather than obtaining an IRIG-B circuit via microwave or leased circuit, it is now desired to utilize the GOES transmission to accomplish this. As utilities invest more and more into this GOES receiving equipment, a concern always remains for this time service to continue in the future.

Transmittal of remote data from digital fault recorders and sequence of events recorders to a master station is now becoming a very useful data gathering tool. Rapid fault and disturbance analysis is now possible, but date must be time synchronized to be meaningful. SER data interlacers that interweave remote data from many substations must have accurately time synchronized remote SER's to prevent incorrect interpretation of the outputs. Digital fault recorders with event recording capability will also be required to have time sync capability such as IRIG-B to insure proper data analysis.

Data requirements by various regulatory agencies make accurate timing analysis even more important during system disturbances or critical generating plant outages. Taking the guesswork out of when events occurred will make the data analysis more meaningful. A wealth of information will be available to analyze system parameters as well as equipment performance if sufficient effort is applied to understanding the data.

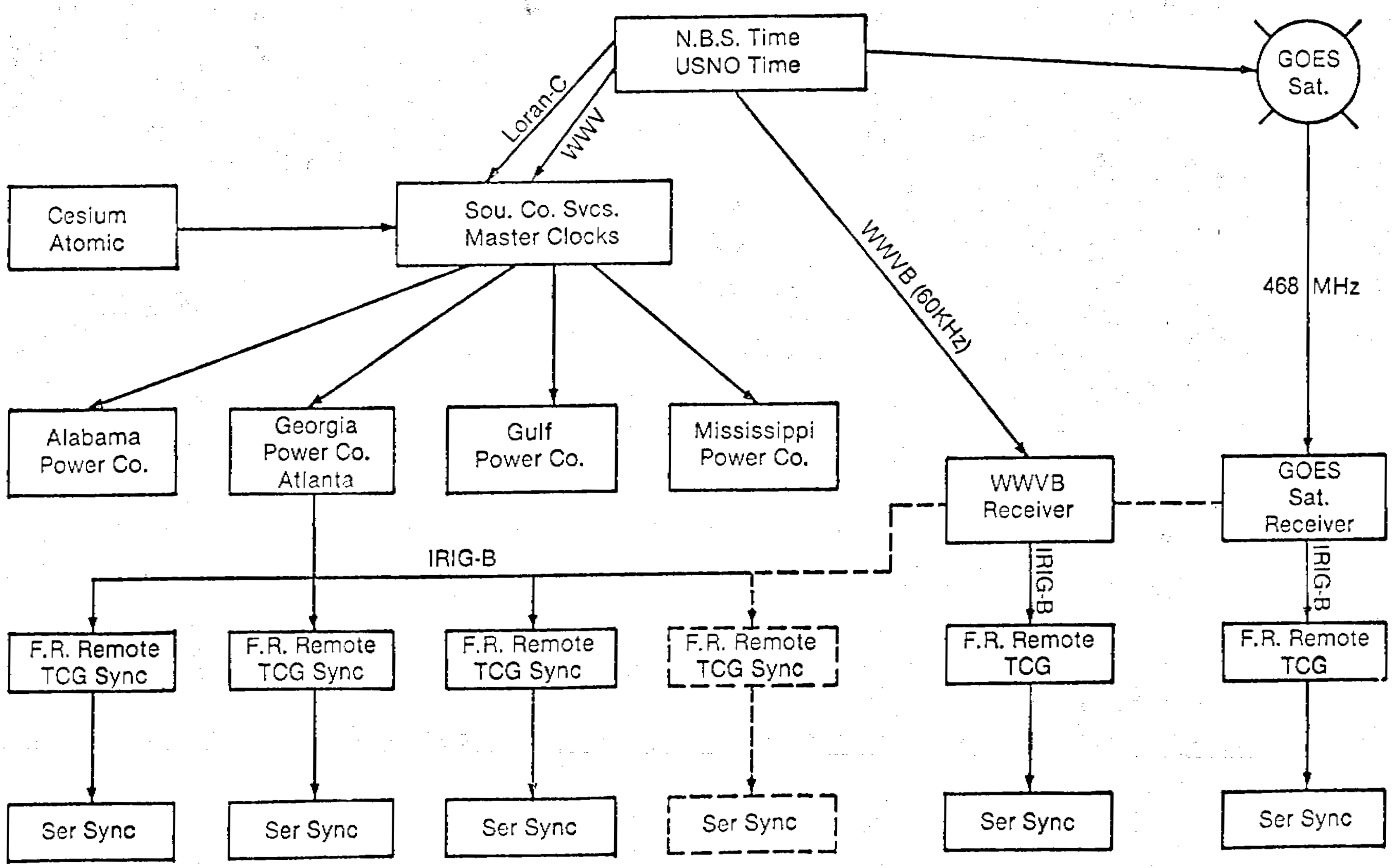
CONCLUSIONS

In summary, this synchronized timing system consists of a master station transmitting continuous time code (traceable to NBS) to various remote locations. The received time data is displayed and buffered for recording on the magnetic tape and events recorders with propagation delay accounted for. If no company owned communications facilities are available, equipment is installed for receiving the time data as transmitted from the GOES satellites. This essentially takes the place of the microwave channel equipment. A portable atomic clock is carried to each location to measure time delays and insure the IPPS signal is synchronized to all other IPPS signals. The goal is to have all recorded times within 1 millisecond of each other at all locations.

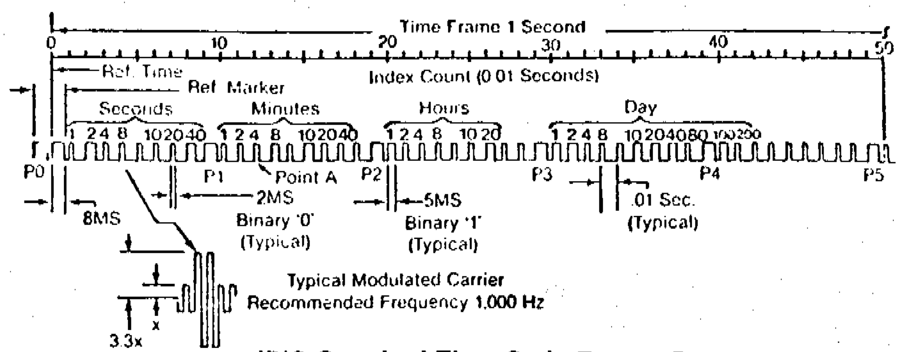
Field experience has indicated the above goals are obtainable on a consistent basis. This timing system not only allows accurate data comparisons between Georgia Power Company recorders, but also provides common time base data for three other operating companies within the Southern Company.

While considerable progress has been made since this project conception, newer methods and improved equipment will allow future improvements as requirements change. One area of even more accurate time and frequency dissemination to be used in the future will utilize the Global Positioning Satellites (GPS) as a master time source. Extreme accuracy in the microsecond region will allow regional phase angle measurements to be made.

Presently the combination of continuous monitoring magnetic tape fault recorders, digital fault recorders, sequence of events recorder, and a real time clock synchronizing system provides extremely valuable fault data while allowing determination on a real time basis of events happening over a very large transmission system.

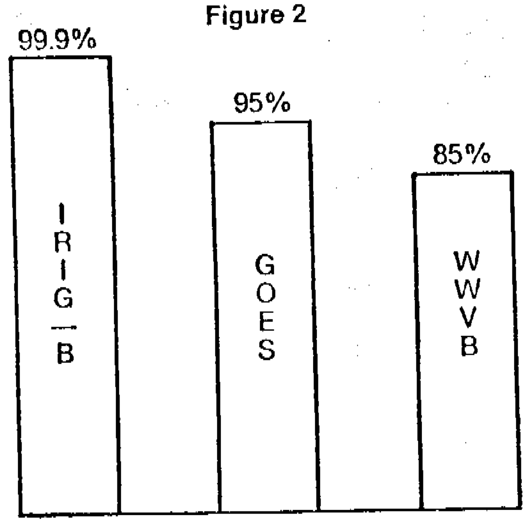


Timing System Block Diagram



IRIG Standard Time Code Format B
Figure 1

Synchronism Lock
Figure 2



System Comparisons
Figure 4

	IRIG-B	WWVB	GOES
Installed Cost	High	Moderate	Moderate
Sync Lock	99.9%	85%	95%
Reliability	Very High	Dinural Effect	Eclipse Periods
Installation Time	High	Very Low	Very Low
Turn-On Times	Immediate	Long 5-60 Mins.	Moderate 5 Min.

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