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Successful Mitigation of Week Roll Over Issue of Global Positioning System in Indian Power System – A Case Study

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Abstract **— Power System utilizes precision timing for Grid monitoring & situational awareness to coordinate operation, integration and protection of Grid elements. Clocks needs to be precisely synchronized to common reference to enable integration of diverse data types and sources to assure that decentralized, parallelized analysis & control actions are effectively coordinated and implemented. Accurate time signals play vital role in analyzing source of fault by assessing the event logger & disturbance recorder data with time stamping. Not only operational & monitoring technologies viz. SCADA, PMUs are time dependent, commercial settlements like DSM, ABT, Billing, etc. also cannot be carried out with non-synchronized time signals. Accurate, consistent and uniformly aligned time is mandatory for mission critical applications such as closed loop wide area controls & real time operator decision support. Power system cannot afford even a single time glitch. Week Number Roll Over (WNRO) is one such issue which if not attended timely may result either in mal-operation or fetching misleading information. This paper discusses the issue of WNRO, its genesis, possible adverse impacts on power system operation and control. The paper also presents comprehensive strategy followed for successful mitigation of WNRO in Indian Power System.**

Keywords **—** ***Epoch, GPS, SCADA, Week Number Roll Over.***

I. INTRODUCTION

POWER system parameters, viz., voltage, frequency, active and reactive powers, etc. are now a days being controlled with the help of information technology through SCADA, PMU etc. To obtain accurate and synchronised results, all data should be in the same time horizon. For this, time stamping of various real time information is done using server time which is synchronized through the Global Positioning System (GPS) standard time signal. Therefore, any abnormal change in GPS signal will have a direct impact on the entire power system. Due to intrinsic design and the then design limitations, GPS encounters week number rollover issue every 19.7 years. The remedial action in time, if not taken may have disastrous effect on any Power system. A week rollover event took place on 7th April, 2019 at 0530 Hrs which was handled successfully without any outage.

II. GENESIS OF GPS WNRO ISSUE

GPS is a space based radio navigation system that allows land, sea and airborne users to determine their exact location, velocity and time 24 hours a day in all weather conditions anywhere in the world. GPS as standard time signal has become an integral and critical part of Power System operation in India. Being so widely used today in critical utilities like Power, Aviation, Industry, Defense, Weather, Transportation etc., GPS has some inherent design challenges that needs to be addressed regularly to avoid any fallout of the adverse impacts of the same. These challenges include WNRO apart from other issues. WNRO issue may pose major challenges in power system operation and control if not resolved before time. Critical infrastructure owners & users should be aware of the GPS WNRO occurrence and the potential impacts it may have on the operation of the critical power system

The GPS receiver based on the navigation signal and computations derives a standard universal time called Universal Time Coordinated (UTC). An offset is applied based on the location of GPS receiver to arrive at the local standard time. A GPS receiver as per design arrives at the current standard time using week number and the count of seconds in the current week. These two information are made available to the receivers with the help of navigation messages from the GPS constellation of satellites (24 Nos). GPS uses a 10 bit field in its legacy navigation message (LNAV, ICD-200) to encode the week number. Ten bit field means 2^{10} i.e. a maximum of 1,024 weeks (19.7 years), could be handled. Each of these periods is known in GPS terms as an "epoch". At the end of each epoch i.e. 1,024 weeks, the receiver resets the week number to zero and starts counting again. Figure 1 depicts the standard epoch cycle.

As the GPS services were launched, first WN parameters in the GPS Navigation message started at 0000Hrs of Jan 6, 1980 meaning that the first epoch of GPS time lasted until 21 August 1999. Subsequently, GPS time was running in the second Epoch which also ended on the 6 April, 2019.

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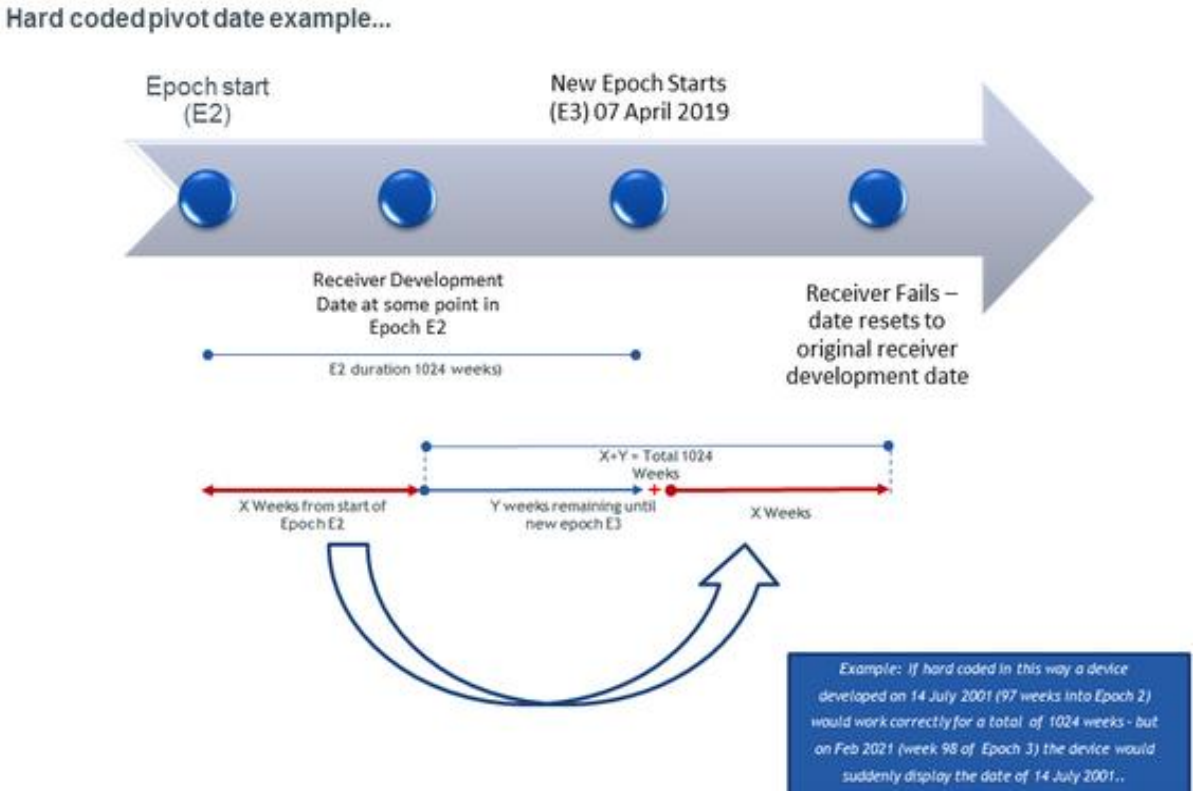


Fig. 1. Standard Epoch Cycle

As part of the modernization program of the GPS, 13 bit (2^{13}=8192) implementation has been effected with CNAV type of navigation message for civilian use. With 13 bit implementation the GPS epoch would be 8192 weeks i.e. almost 157 years long. This practically would solve the WNRO problem.

GPS provides uniform time signal and does not take into account the leap seconds being encountered from time to time. Therefore, the week count would become '0' 18 seconds (leap seconds so far since 1980) prior to 0000 Hrs of 7th April, 2019. That means from this time onwards, rollover problems in GPS receivers might be observed if they were not programmed to cope up with the week number reset properly. This would result into erroneous date/time string affecting the normal functioning of the systems based on GPS. WNRO affecting critical systems like weather balloons, Boeing planes, have already been reported from Australia. Similarly, aircrafts of China Airlines also got affected due to unpatched GPS.

III. Potential problems due to WNRO Issue

There can be two set of issues that may be observed if GPS is not ready for WNRO:

A Immediate effect after WNRO

This happens to the GPS receivers having their GPS epoch start date as per the original epoch (21 August 1999). These systems can result in time stamping to dates going 1024 weeks back and thus may cause issues with real time power system data.

B Deferred effect for vendors whose GPS epoch starts at the time of Firmware Compilation

Many GPS receiver manufacturers have sought to maximise the default lifespan of their receivers by implementing the 1,024-week limit from the date their firmware was compiled, rather than from the GPS epoch start date. Therefore, these GPS will be impacted later on based on the time of their 1024-week completion according to the firmware compilation date.

IV. Probable Impact on Power System Monitoring using SCADA and WAMS

Commissioning of SCADA and WAMS generally takes place in different stages and many a times have more than one manufacturers in a grid. Also, the adoption of GPS may differ i.e. 10 bit or 13 bit and whether the synchronization of GPS is done w.r.t last epoch or the firmware compilation date has been considered. Due to these differences, it becomes inevitable to adjust the GPS time at the end of each

epoch so as to have hassle free Power System operation. The following are the probable impacts on the Power system monitoring and control

A Wrong time stamping of data dating back to last epoch

This can lead to data being treated differently by real time visualization display of SCADA (Supervisory Control and Data Acquisition) and WAMS (Wide Area Measurement System).

B Mismatch between PDC (Phasor Data Concentrator) and PMU (Phasor Measurement Unit) time stamp

PMU measurements at the PDC may be dropped due to perceived latency of incoming data frames due to the mismatch between PMU and PDC time-stamps.

C Abnormal /inconsistent behavior of the applications developed on PMU based systems.

V. Solutions to the WNRO Issue

Following methods have been in prevalence for tackling the WNRO issue by various OEMs:

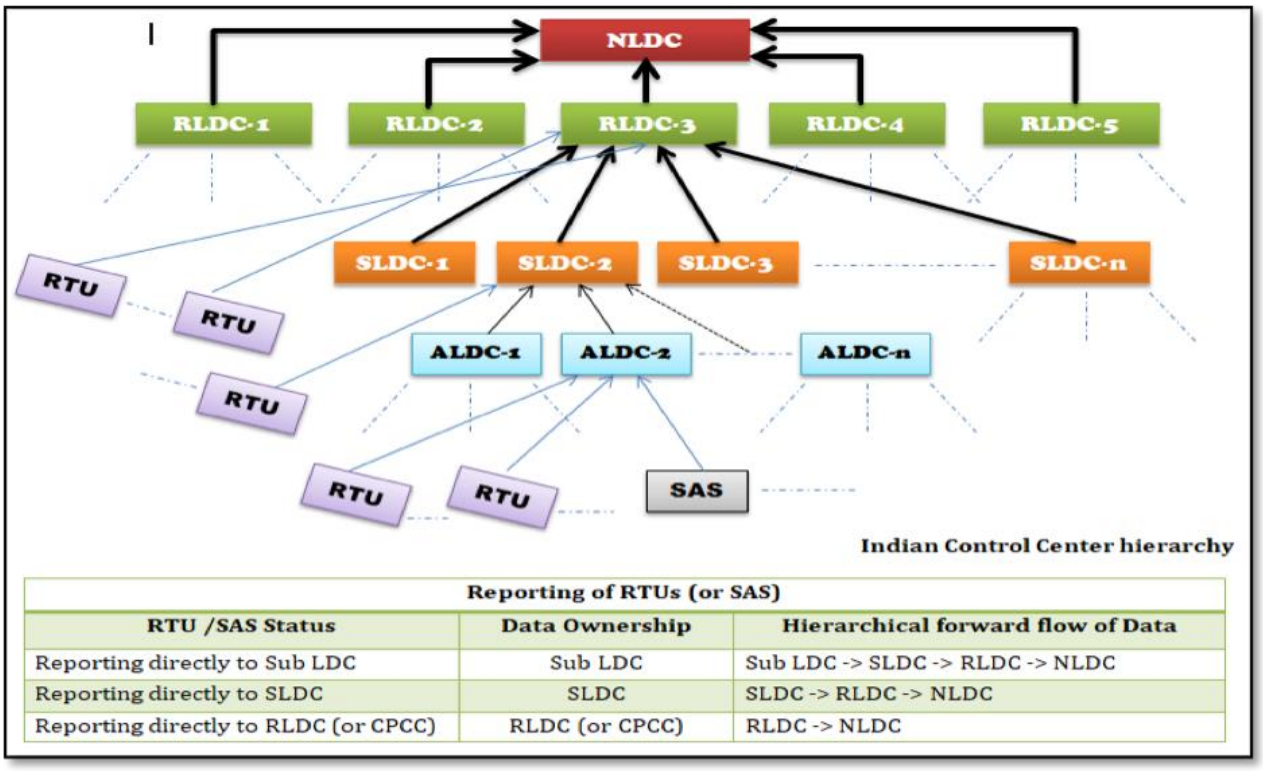
A. Compilation date of receiver firmware

Modification of the epoch start year e.g. making it 2019 in the firmware of the GPS receivers would make them ready for further 19.7 years from the date of firmware compilation.

Fig. 2. Upgraded GPS Receiver

B. Implementation with upgraded GPS signal

Following the upgraded GPS signal with CNAV (Civil Navigation system) where 13 bits have been provided for the week number. This will facilitate the receivers to last up to the year 2137 long enough for the current technology. Figure 2 shows the upgraded GPS receiver.



Reporting of RTUs (or SAS)		
RTU /SAS Status	**Data Ownership**	**Hierarchical forward flow of Data**
Reporting directly to Sub LDC	Sub LDC	Sub LDC -> SLDC -> RLDC -> NLDC
Reporting directly to SLDC	SLDC	SLDC -> RLDC -> NLDC
Reporting directly to RLDC (or CPCC)	RLDC (or CPCC)	RLDC -> NLDC

Fig. 3. Hierarchical Structure of Control Centre in India

VI. Strategy to Mitigate the WNRO Effect in Indian Power System

A well co-ordinated strategy in sensitization, data collection and corrective measures was undertaken pan India by the Independent System Operator in India. All the OEMs, utilities & other stake holders in Indian power sector were taken in to the consultative process.

Hierarchical structure of data reporting is as shown in Figure 3. Regional control centres collected the information related to GPS deployed in critical systems with various utilities in the concerned region, analyzed the information which helped in taking prompt action wherever needed. In most of the potentially vulnerable cases, the firmware were upgraded by the concerned GPS OEMs. Further, in some cases wherever it was not feasible to replace the firmware, the critical systems were isolated from the vulnerable GPS. In order to ensure continuous availability of the critical systems, alternate compliant GPS were made available well before the WNRO scheduled date.

For smooth flow of information, the responsibilities were assigned as per the hierarchical structure of the control centres for system operation in India (Fig. 3).

VII. Case Studies

Case Study 1

GPS installed at one of the DISCOMs in Northern Region lost signal, got locked and the time was frozen. When it was reset, it switched over to the year 1999 i.e. start of the then current GPS epoch. This GPS was deployed for time synchronization of its SCADA system. During the sensitization process, this GPS was suspected to be WNRO non-compliant and as a precautionary measure, it was isolated from the critical SCADA system. Figure 4 shows the real picture of faulty GPS which switched over to start of epoch i.e. year 1999.

Status of GPS before the due date of WNRO

Fig. 4. WNRO Non-Compliant GPS

Status after WNRO

Case Study 2

GPS Used for Time Synchronization of SCADA System at one of the Back up SLDCs in Southern Region.

Fig. 5. GPS Isolated from SCADA

The GPS was installed at one of the SLDCs in Sothern Region for time synchronization of the SCADA system. This GPS too was suspected to be WNRO non-compliant. Therefore, the GPS unit in question was isolated from the SCADA system in order to mitigate the possible implications in the critical functions of the SLDC SCADA system (Fig. 5). This GPS unit showed a surprising behavior in switching over 6th January, 1980 (Fig. 6) i.e. start of first ever epoch of GPS rather than switching to the start of the current epoch i.e. 1999.

Fig. 6. GPS Switching to year '1980'

Experience & Learnings from Case studies

From the above case studies it is clear that if prior action of identification and isolation was not undertaken, the critical SCADA, IT & WAMS systems might have been affected with regard to their

availability and data quality. Mismatch of the GPS time might have affected the situational awareness thereby impacting decision support systems deployed for the real time system operation in India.

During the implementation of the strategy for mitigation of the WNRO issue, several glaring issues connected with the prevailing GPS equipment, their OEMs (Original Equipment Manufacturers) and lack of standardization came to the fore. Most of the GPS equipment have been manufactured and supplied to the stake holders in Indian power sector have lacked standards with regard to the treatment of WNRO. Moreover, during the mitigation process, some of the OEMs were not pro-actively keen about mitigating the issue. However, with continuous persuasions with the OEMs and all vendors at different platforms, they agreed to resolve the WNRO issues in an amicable manner.

VIII. Conclusion & Way Forward

As a result of coordinated efforts and strategy implemented by the System Operator, Power Systems in India remained free of any incident of WNRO.

Further, all the information of GPS deployed with critical systems have been compiled to keep a close vigil specially wherever the firmware has the compilation date as the start of the GPS epoch i.e. year 1980. In such cases, the WNRO would happen on the later date rather than the GPS epoch start/end date which must be taken due care in future. However, it is strongly advised that WNRO issue should be addressed in the design stage itself as systems are bound to become increasingly complex in times to come. The strategy undertaken in this epoch may not be feasible in such upcoming complex systems, therefore, all the new GPS receivers must be based on 13 bit implementation of WNRO as per the modernized GPS CNAV system.

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