Design and Development of Micro Phase Measurement Unit for Synchro-Phasor Measurement Used in the Next Generation Resilient Micro-Grid

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Abstract- This paper introduces the design and implementation of a Micro Phase Measurement Unit (PMU) tailored for synchrophasor measurements, addressing the growing need for resilience in future microgrids[1]. The proposed device is constructed using the TMS320F28069M Launchpad from Texas Instruments, providing a space-efficient and effective solution ideal for distributed energy networks. To ensure precise time synchronization, the system incorporates an L89 NavIC receiver that generates a Pulse Per Second (PPS) signal, enabling accurate timestamping crucial for synchrophasor applications. Furthermore, bespoke software implementing Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT) algorithms has been created to measure and evaluate input current phasors in real-time. This integrated approach improves phase measurement accuracy and computational performance, which are vital for efficient monitoring and management of resilient microgrid operations. Empirical findings validate the viability and durability of the developed PMU, emphasizing its potential to support advanced grid functionalities and future resilient power systems.

Indexed Terms—Phasor-Measurement, Micro-Grid, Gridresilience, Synchrophasor, Distribution Networks.

I. INTRODUCTION

The integration of renewable energy sources and advancements in smart grid technologies have fostered the development of resilient microgrid systems, offering enhanced reliability and sustainability in power distribution networks. Central to these systems is the design and implementation of a compact Micro Phasor Measurement Unit (PMU) for synchronization applications in low-voltage distribution networks and isolated microgrid segments. Built on Texas Instruments' TMS320F28069M Launchpad, the Micro PMU incorporates an L89 NavIC receiver to ensure precise synchronization using a Pulse Per Second (PPS) signal for accurate timestamping in synchrophasor applications. It employs sophisticated signal processing techniques, including Discrete Fourier Transform (DFT) and Fast Fourier Transform (FFT), for real-time analysis of electrical parameters such as voltage, current, and phase, enabling precise phasor extraction. This study details the PMU's design methodology, synchronization integration, and DFT algorithm execution, supported by empirical results demonstrating its efficiency in enhancing the stability and reliability of microgrid operations.

II. LITERATURE REVIEW

[1] E. Dusabimana and S.-G. Yoon, "A Survey on the Micro-Phasor Measurement Unit in Distribution Networks," *Electronics*, vol. 9, no. 2, p. 305, Feb. 2020, doi: 10.3390/electronics9020305.

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[13]NavIC SIGNAL-IN-SPACE ICD FORSPS VERSION 1.1

III. IMPORTANCE OF SYNCHRONIZED MEASUREMENTS

The need for synchronized measurements in microgrid environments arises due to several factors. Firstly, in interconnected power systems, accurate synchronization is essential for maintaining grid stability as instability in the grid can cause power blackouts and ensure the reliable operation of interconnected generation and transmission assets. Synchronized measurements provide real-time information about voltage, current, and phase angle across different points in the grid, allowing operators to identify and address potential issues such as voltage instability, phase imbalances, and frequency deviations.

Furthermore, synchronized measurements enable advanced grid monitoring and control functionalities such as fault detection, island detection, and optimal power flow control. By synchronizing measurements from multiple sensors distributed throughout the microgrid, operators can detect abnormal grid conditions in real time and implement corrective actions to mitigate potential risks and ensure system reliability.

In microgrid environments characterized by the integration of distributed energy resources (DERs) and decentralized control strategies, synchronized measurements are critical for coordinating the operation of DERs and maintaining grid stability. By synchronizing phasor measurements across distributed sensors and control devices, microgrid operators can effectively manage the dynamic interactions between DERs, grid-connected loads, and energy storage systems, thereby optimizing energy dispatch and minimizing the risk of grid disturbances.

IV. NEED FOR MICRO-PMU OVER TRADITIONAL PMU

In contrast to traditional Phasor Measurement Units (PMUs), Micro-PMUs offer a compelling solution tailored to the evolving needs of modern power distribution networks. Traditional PMUs, designed primarily for high-voltage transmission systems, often lack the scalability, cost-effectiveness, and adaptability required for deployment in distribution grids. Micro-PMUs address these limitations by offering a compact form factor and lower installation costs, making them suitable for widespread deployment at distribution substations and even on individual feeders. Furthermore, their enhanced resolution and localized measurement capabilities enable finer granularity in monitoring grid dynamics, facilitating improved situational awareness and more targeted control actions.

V. HARDWARE AND SOFTWARE REQUIREMENT

A. L89 GNSS Receiver

The L89 NavIC receiver was chosen for its ability to provide highly accurate UTC timestamps every second by using multiconstellation support, including IRNSS (NavIC), Galileo, and GPS systems. Its compatibility with standard serial communication made it easy to interface with the microcontroller, while its low power consumption and compact form factor suited the design requirements of the Micro PMU. Moreover, the L89 offered reliable positioning and timing even in challenging environments, which was essential for ensuring precise time synchronization in phasor measurements.

B. TMS 320f28069M

The TMS320F28069M microcontroller was selected for this project due to its high-performance processing capabilities, integrated floating-point unit, and specialized support for real-time control applications. Its fast ADCs, efficient PWM modules, and on-chip peripherals make it highly suitable for accurate sampling of analogue voltage and current signals in phasor measurement. Additionally, its compatibility with Code Composer Studio and robust support for C2000 libraries simplified the development of real-time algorithms such as DFT

C. Current Transformer Voltage Transformer circuits

Current and voltage transformer circuits were used to scale down the high-voltage and high-current signals from the power system to safe, measurable levels compatible with the ADC inputs of the TMS320F28069M. These circuits ensured electrical isolation, protected the microcontroller from surges, and maintained signal integrity necessary for accurate phasor calculation. Proper scaling and filtering helped in precise sampling without distortion or noise amplification. This was critical for reliable DFT-based extraction of magnitude and phase information in the Micro PMU.

D. Code Composer Studio IDE

Code Composer Studio (CCS) IDE was selected for developing and debugging the firmwae because it provides a seamless and optimized environment specifically designed for Texas Instruments (TI) processors like the TMS320F28069M.

Fig. 1. Code composer studio (TM).

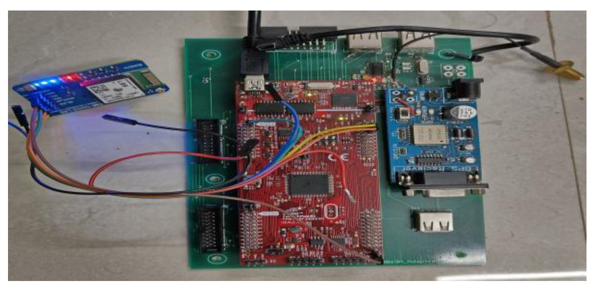

Fig. 2. TMS 320f28069M microcontroller along with L89 receiver.

VI. METHODOLOGY

The workflow involves the following steps:

1) Configuring the L89 Navic Receiver As initially the L89 receiver sends a bulk of data,some NMEA commands are being required to be send to the receiver to send only the desired output which is timestamp in our case. Commands were passed to the receiver with the help of PowerGPS software tool.

Fig. 3. Current-Voltage transformer circuit with analogue inputs.

2) Developing a C code in Code composer studio Developed an embedded C code in CCS IDE to implement Discrete Fourier Transform (DFT) algorithm to calculate the phasor values from the real-time data acquired from the ADC module of the microcontroller . Using appropriate command, header, linker files to interface TMS 320f28069M microcontroller to the computer.
3) Debugging the code The code was dubugged for multiple errors and some issues which were faced with the command,header and linker files required for the microcontroller to execute the C code.
4) Using a USB-Serial converter The USB-Serial converter facilitates communication between the L89 NavIC receiver and the computer by converting UART signals to USB. It enables configuration and data logging by connecting the receiver's serial interface to the computer's USB port. The converter supports adjustable baud rates and flow control mechanisms, ensuring compatibility with the receiver. This interface ensures reliable data transmission for receiver setup and monitoring in terminal software.
5) Real time monitoring Timestamp from the L89 receiver and the real-time phase values were monitored using the real-time debugger module and the in-built terminal of the Code Composer IDE.

VII. RESULTS AND ANALYSIS

A. PowerGPS commands B. Phasor values with the timestamp

Timestamp data in UTC format was received every second from the multi-constellation system comprising IRNSS, Galileo, and GPS satellites. The Timer creates an interrupt every second and triggers the DFT module which calculates the Discrete Fourier Transform (DFT) values of the sampled input and stores the result in the Vph[] array. The phasor values are being displayed using the debugger module in parallel with the terminal showing the real-time timestamp data from the satellite constellation.

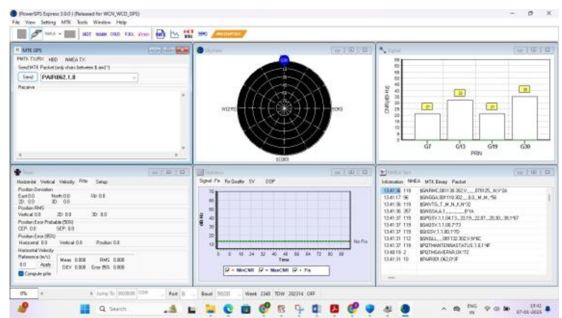

Fig. 4. PowerGPS command1

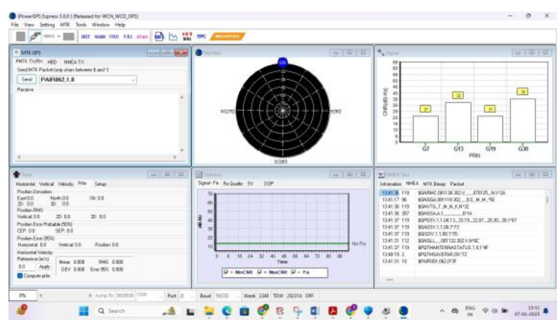

Fig. 5. PowerGPS command2

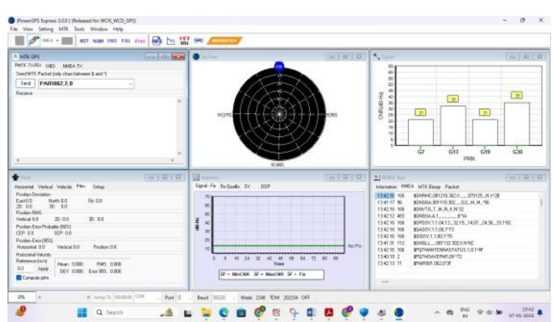

Fig. 6. PowerGPS command3

CONCLUSION

In conclusion, the development of the Micro Phasor Measurement Unit (PMU) system represents a significant advancement in synchronization technology for resilient microgrid environments. Through the integration of precise timing signals from the L89 receiver and the computational capabilities of the DSP TMS 320f28069M microcontroller, the system offers real-time monitoring and control of electrical parameters within microgrids. The Code composer Studio facilitates seamless programming and interfacing with the TMS 320f28069M , streamlining development processes and enabling rapid prototyping. By leveraging these technologies, the project aims to enhance grid stability, optimize energy dispatch, and support the integration of renewable energy sources. Moving forward, further research and development efforts will focus on refining the system's performance, expanding its capabilities, and promoting its adoption in real-world microgrid applications, thereby contributing to the advancement of sustainable and resilient energy systems.

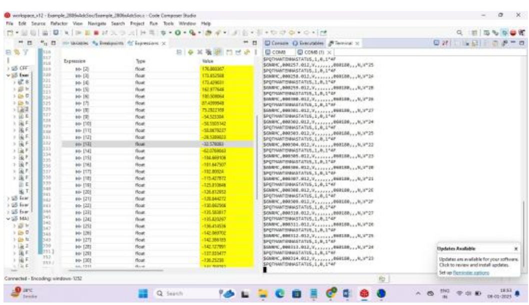

Fig. 7. PowerGPS command4

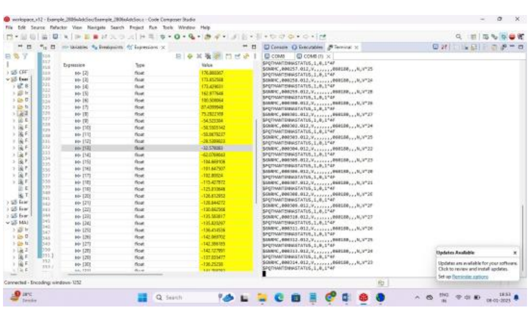

Fig. 8. Phasor values with the timestamp

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