ISSN: 1672 - 6553

JOURNAL OF DYNAMICS AND CONTROL

VOLUME 10 ISSUE 03: P234-241

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JOURNAL OF DYNAMICS AND CONTROL
https://doi.org/10.71058/jodac.v10i03008

COMPARATIVE ANALYSIS OF MANUAL AND SOFTWARE-BASED COMMISSIONING APPROACHES FOR SINAMICS G120 AC DRIVES: A REVIEW

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Abstract: *The role of the SINAMICS G120 series variable frequency drive (VFD) has been instrumental in the field of industrial control systems and the control of AC induction motor drives that contribute to optimized energy efficiency. Thus, the present paper aims to carry out an in-depth comparative study and analysis of the commissioning of the SINAMICS G120 AC drive system, comparing the manual mode of commissioning, which may be achieved through the use of operator panel devices such as BOP-2 or IOP, and software commissioning achieved through tools such as 'Start Drive in TIA Portal.' Moreover, through experimental models of the 1.5 kW rating AC induction motor, the performance evaluation of the result will be discussed in detail. Different case study scenarios have already proven that software commissioning offers reliable results, i.e., 32% less rise time for speed, 66% less error, and thus efficient startup, ensuring higher energy savings. Research gaps were identified in PLC-VFD control systems, which have been addressed in the current study for application within Industry 4.0 scenarios.*

Keywords: *SINAMICS G120, Variable Frequency Drives, Commissioning Methods, PLC Integration, Industrial Automation, Energy Efficiency.*

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1. Introduction:

The transformation process to Industry 4.0 technology requires better motor drive technology with high-performance characteristics and digital integration within the industrial automation system. In this scenario, Variable Frequency Drives (VFDs) have been playing a crucial role for Industry 4.0 technology advancements and motor parameter control. The Siemens SINAMICS G120 drives are a part of modular AC drive technology, consisting of a Power Module (PM) and a Control Unit (CU) for real-time motor control and communication. With the implementation of IGBT technology-based PWM inverters and V/f and vector control modes, the G120 can be adopted for variable torque and constant torque operation. From a control point of view, G120 drives take advantage of field-oriented control (FOC), which allows torque and flux components to be separated, thus offering a high accuracy and dynamic response over a wide speed range. The ability to connect PLCs and SCADA systems directly to foundation field bus protocols (PROFINET and PROFIBUS) therefore allows for seamless integration between condition monitoring and predictive maintenance systems. In addition, the use of variable speed drives improves energy efficiency by reducing energy lost in the process flow by as much as 50 %. A critical part of the implementation of an integrated PLC-VFD system is commissioning. If systems are not properly parameterized, malfunctions may occur. This study reviews the different methods of commissioning using either manual or automated software approaches and develops an effective comparative analysis of the two methods in the context of industry. It seeks to close the gap in the experimental documentation of actual applications involving integrated PLC - VFD systems.

1.1 Literature Review

VFDs are now widely used for controlling induction motor behaviour in industrial applications because they provide a quick technology that is both efficient and gives more flexibility over an induction motor's entire speed range. VFDs achieve this by changing the voltage to motor's windings as the frequency of the power supply is changed at a constant Volts per Hertz relationship. As a result, VFDs maintain a constant level of airgap flux and stable torque throughout all speeds that are possible by an induction motor.

The advances in power electronic devices, especially the use of IGBT based inverter is reported to have provided dramatic improvements in the performance of AC drives. The use of a PWM technique to generate the AC voltage without introducing the normal amount of harmonic content has made PWM techniques such as sinusoidal PWM and space vector PWM much better; creating a better voltage profile, reducing the harmonic distortion, providing a better power factor, and having a better dynamic response for controlling induction motor drives in very demanding applications.

VFD-controlled motor systems have long provided significant energy savings in various fields, especially in relation to variable-torque applications, and through experimental and field testing it is proven that these systems will produce significant energy savings over fixed-speed motors, thereby increasing operational efficiency and sustainability [5]. While there are numerous examples of the successful implementation of these systems, a range of issues have also been noted in the literature, including: propagation of harmonics; excessive dv/dt stresses on the motor insulation; and thermal limitations during

low- speed operation; therefore proper matching and protection of the motor to the drive is critical [6].

The combination of Programmable Logic Controllers (PLCs) with variable frequency drives (VFDs) has also provided additional opportunities for the expanded functionality and variety of dynamic utilizations of AC drive systems for automation control applications, as these systems (typically) implement an algorithmic control scheme through the processing of sensor feedback, as well as the implementation of safety interlocks, thus demonstrating their suitability for many of the complex automation tasks that they might typically be performing [7-9]. For example, with respect to crane and hoisting systems, vector control drives with auxiliary control from a PLC can improve the load-handling capacity, overall brake performance, etc.

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The use of advanced devices in feedback, i.e., encoders, tachometers, etc., enables accurate speed control, resulting in improved system accuracy during steady-state operation and in response to various loading effects [11]. Moreover, PLC integration with SCADA/HMI systems improves overall system reliability by enabling real-time monitoring and response, mitigating the undesirability that often characterized conventional control systems. [12].

Comparative studies based on the open-loop and closed-loop PLC-controlled induction motor drives show that closed-loop configurations offer better speed regulation and robustness, whereas open-loop V/f speed control is still considered a popular choice in cost-effective and less demanding applications [13,14].

In summary, from the literature review, there is no comprehensive and integrated analysis that treats simultaneously drive modernization, harmonic mitigation, energy savings, motor protection, and PLC migration under a unified approach, validated under industrial running conditions. This research gap motivates the present work, which aims to experimentally evaluate an integrated PLC–VFD-based AC drive control architecture suitable for scalable and real-time industrial automation applications [15].

2. Integration of SINAMICS G120 with Siemens PLC Using PROFINET

System Architecture: The system comprises a 3-Φ Induction Motor, SINAMICS G120 drive, and S7-1500 PLC connected via the PROFINET. In the power layer, AC-DC-AC conversion occurs, and in the control layer, algorithms are carried out, while in the communication layer, real-time exchange takes place.

In the fig. 1, Sequential process of system architecture is shown, in which power layer, control layer and communication layer are clearly mentioned.

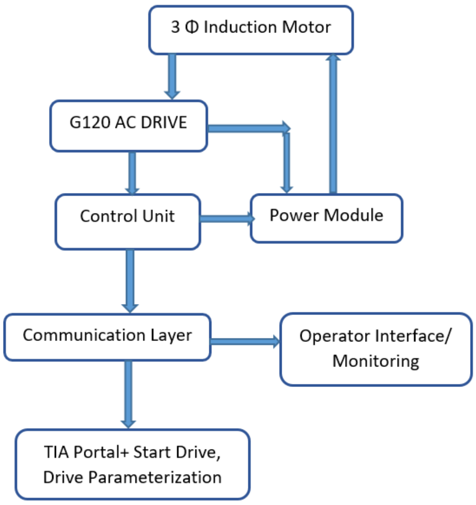

Fig.1 System architecture of SINAMICS G120 with Siemens PLC using PROFINET.

PROFINET Communication: Cyclic Process Data Objects (PZD) use telegrams for control (e.g., Control Word, Speed Set point) and feedback (e.g., Status Word, Actual Speed). Acyclic communication accesses parameters.

3. Methodology

The commissioning process of the servo drive system with an encoder follows a specific sequence of events and can be completed within a finite number of steps. It starts with the hardware setup and implementation of encoder feedback for position and speed detection. This is followed by the

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parameterization of the servo drive using Siemens' Start Drive software. This program allows for motor parameterization to achieve maximum efficiency with the drive motor. After successful completion of motor parameterization, the next step is to program the PLC using Siemens' TIA Portal software. When programming has been completed, data mapping will occur for creating communication linkages between this system and other devices to allow for smooth transfer of position/speed references. The final step to accomplish performance evaluation is through application of realistic loads to the system.

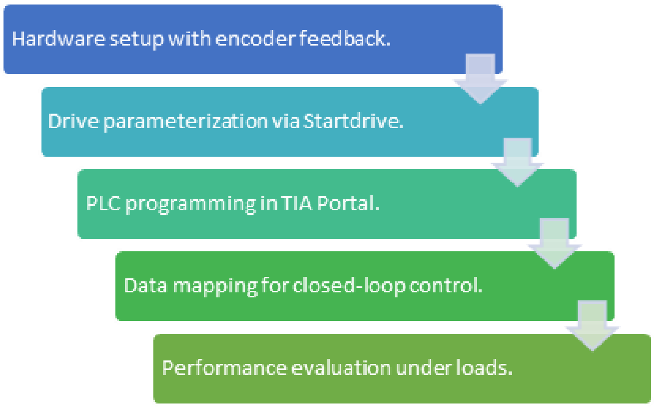

Fig.2 Acyclic communication accesses parameters.

4. Manual Configuration of SINAMICS G120

Hardware Required

- G120 Drive (PM + CU)
- Operator panels (BOP-2/IOP)
- Power supply and motor

The AC Drive was configured using a standardized procedure that guaranteed safe, reliable, and efficient motor operation. The configuration process started from the initialization and ended at operational validation.

Initially, the drive was powered ON to ensure the control, monitoring, and protection of the internal systems were enabled. The necessary access level was defined to allow the necessary parameters to be modified appropriately.

The parameters of the motor name plate were next input to the drive. Proper parameterization is required in order to appropriately implement control algorithms and also protect the motor.

Based on the requirements for the application, the control method was derived from various options such as volts per hertz control, vector control, or torque control. The choice of the control method affects the performance of the drive motor set.

Thereafter, the command and references were configured by allocating the start/stop command, speed references, and feedback signals to the keypad, digital inputs, analog inputs, and communication interfaces, respectively. Finally, once all parameters were set, the configuration data were saved in the non-volatile memory of the drive to maintain data retention even after power interruption.

Finally, the drive had to be tested by running it under no-load or light-load conditions to ensure the motor rotate in the correct direction and the speed responds as expected. Following this test, the drive was ready for normal operation in an industrial setting.

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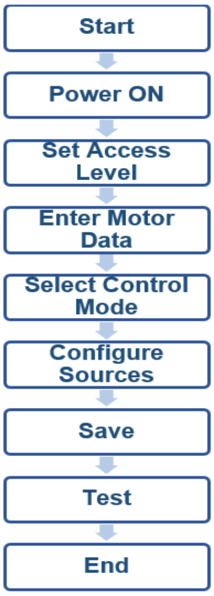

Fig.3 Manual Configuration of SINAMICS G120

5. Software-Based Configuration of SINAMICS G120

- Start Drive in TIA Portal
- Communication cables (USB/PROFINET)

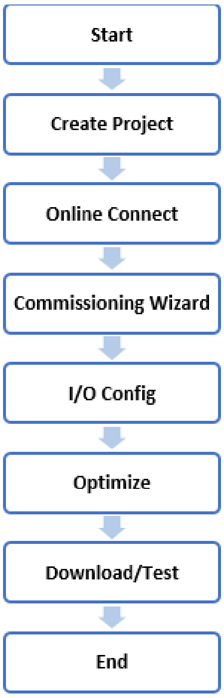

Fig. 4 Configuration of SINAMICS G120 using software TIA Portal

To set up and commission the drive, create a new project, select the components and enter the relevant addresses, and then create an online connection to the drive to allow the software to automatically detect and download the key parameters. Progress through the wizard to enter the essential information about the motor, such as nameplate data, and set the mode to the desired control mode, as well as

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determine the command source to be local or fieldbus. Set the I/O and safety functions to relevant digital and analog input references or signals and set the safety functionality such as Safe Torque off (STO) and Safe Stop 1 (SS1). The optimization process involves running the motor identification process to allow the auto-tuning process to run accurately, set the limits on current, speed, and torque, and finally set the ramps to desired values. Download the configuration to the drive and test it to run under load conditions; also, view the real-time data, which can be in the form of current, speed, and torque to make the required adjustments

6. Comparative Analysis

Motor Ratings

Table.1 Motor Ratings

Parameters	Ratings
Motor	3 phase Induction Motor
Frequency	50hz ±5 %
Voltage	415volts ±10%
Current & Power	0.61A & 0.18KW
Speed	1370
Power factor	0.73

Power Module Ratings

Table 2: Power Module Ratings

Model	Power Module PM240-2
Input	3 phase AC 400-480v+/-10% 2.9 A
Output	3 phase AC 0-input v In=2.2 A
Power	0.75KW

Comparison between the manual and software-based configuration approaches with respect to different parameters and performance basis in industrial drive applications is shown in Table 3 and Table 4.

Table 3: Comparison of Configuration Approaches

Feature	Manual	Software- Based
Setup Complexity	Low	Moderate to high
Config. speed	Slow	Fast
Visualization	Limited	Graphical
Diagnostics	Basics	Advanced
Scalability	Low	High
PLC Integration	Difficult	Easy
Stability	Slow Systems	Industrial Automation

Software based configuration are better than manual based approach in almost every features like efficiency, maintenance efforts, fault diagnostics etc. in **table 3.**

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Table 4: Performance Comparison

Feature	Manual	Software based
Startup Smoothness	Moderate	Excellent
Energy Efficiency	Standard	Improved
Maintenance Effort	Higher	Lower
Fault Analysis	Reactive	Predictive
Scalability	Limited	High
Starting Current	High	Optimized
Torque Ripple	Noticeable	Minimal
Fault Diagnostics	Limited	Detailed

Table 4 shows the Performance analysis. This comparison table clearly shows the advantages of software based approach over the manual based. Software Approach provides smoother startup, improved starting current, better energy efficiency, and minimized torque ripple.

Overall, software-based configuration offers better performance, scalability, and trustworthiness, for high-performance and automation-intensive industrial environments.

7. Conclusion

The authors proposed a comprehensive comparative analysis of manual and software-based commissioning strategies of the SINAMICS G120 AC drive, along with experimental results to validate the findings. In the results, the software-based commissioning method of the Start Drive in the TIA Portal was found to perform far better in terms of dynamic response, steady-state accuracy, start current, and reduction of torque ripple compared to the manual method. It is found that these performance benefits are due to the parameterization, motor identification, and inclusion of diagnostics offered by the software-based method.

In addition, the connection of SINAMICS G120 to Siemens PLCs through deterministic communication via PROFINET makes way for Industry 4.0-like scaling of control configurations. Furthermore, commissioning processes can be fully automated to reduce overall commissioning times while improving the level of transparency and maintenance of the process and system optimally. Manual commissioning methods can still be employed for easy and cheap solutions but are limited and can greatly restrict a system due to inflexibility for industrial control processes.

Fig. 5 G120 AC Drive

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On the whole, the results of the research support the earlier assertion that using software commissioning for AC drives produces a reliable, efficient, and scalable answer for modern AC drive-based applications. The results of the present research are directed towards providing useful insights for drive selection and commissioning modes, and potential areas of future research can be extended in the domain of adaptive and data-driven parameter optimization using artificial intelligence methodologies, etc.

Acknowledgment

This is declared that the work is nor presented anywhere neither supported by any public agency or institute.

Abbreviations

VFDs Variable Frequency Drives
PZD Process data
PM Power Module
CU Control Unit
FOC Field-oriented control
PLCs Programmable Logic Controllers
STO Safe Torque off
SS1 Safe Stop 1

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