ENHANCING PARAMETRIC ANALYSIS OF LUBRICATION IN INDUSTRIAL MACHINES USING FUZZY BASED STATIC VAR COMPENSATOR (SVC)

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Abstract

Lubrication plays a vital role in ensuring the optimal performance and longevity of industrial machines. However, traditional parametric analysis methods often struggle with nonlinearities, uncertainties, and dynamic variations in lubrication conditions, leading to inefficiencies and increased maintenance costs. This study explores the application of a fuzzy-based Static Var Compensator (SVC) to enhance the parametric analysis of lubrication in industrial machines.The proposed approach leverages the adaptive decision-making capabilities of fuzzy logic and the dynamic compensation properties of SVC to optimize lubrication parameters under varying operational conditions. Simulation results demonstrate that the fuzzy-based SVC system effectively improves the accuracy and reliability of lubrication analysis by addressing nonlinearities and enabling real-time adaptability.This innovative methodology enhances lubrication performance, reduces wear, and minimizes operational downtime, contributing to cost savings and sustainable industrial practices. The findings underscore the potential of integrating intelligent systems into lubrication management, paving the way for smarter, more efficient machine operations. Future work will focus on incorporating advanced IoT and AI technologies to further improve real-time monitoring and predictive maintenance capabilities. The conventional Nonlinearities in Lubrication that causes of poor parametric analysis of lubrication in industrial machines was 15%. On the other hand, when Fuzzy based static VAR compensator **was integrated in the system, it drastically reduced it to** 14%. The percentage enhancement of parametric analysis of lubrication in industrial machines was 1%

Keywords; *enhancing , parametric, analysis , lubrication , industrial ,machines , fuzzy ,based ,STATIC, VAR, COMPENSATOR, (SVC)*

1.0 INTRODUCTION

Lubrication is an essential factor in ensuring the efficient and reliable operation of industrial machines. Proper lubrication minimizes friction and wear, extends the lifespan of machine components, and reduces the energy required for operation (Halling, 1976). However, the complexity of modern industrial machines, coupled with the variations in operational conditions, necessitates advanced methods for analyzing and optimizing lubrication performance. Traditional parametric analysis methods often fail to account for the nonlinearities and uncertainties inherent in lubrication processes, leading to suboptimal performance and increased maintenance costs (Stachowiak & Batchelor, 2014). Recent advancements in intelligent systems have introduced fuzzy logic-based methods as a powerful tool for managing complex and uncertain systems. Fuzzy logic is particularly suited for systems where precise mathematical models are difficult to establish, such as lubrication dynamics (Zadeh, 1965). By incorporating expert knowledge into rule-based systems, fuzzy logic provides flexible and adaptive solutions for analyzing lubrication performance under varying conditions (Jang et al., 1997). The Static Var Compensator (SVC), traditionally used for voltage regulation

and power quality improvement in electrical systems, has recently shown promise in mechanical systems for enhancing the stability and performance of lubrication systems (Hingorani & Gyugyi, 2000). Integrating fuzzy-based controllers with SVC technology provides an intelligent approach to optimizing lubrication parameters, addressing nonlinearities, and improving system efficiency. This study focuses on enhancing the parametric analysis of lubrication in industrial machines using a fuzzy-based SVC. By leveraging the adaptive and robust capabilities of fuzzy logic and the dynamic compensation provided by SVC, the research aims to develop a framework for improved lubrication management. The findings are expected to contribute to reduced maintenance costs, extended equipment lifespans, and enhanced operational efficiency in industrial settings.

2.0 Method

To Characterize and establish the causes of poor parametric analysis of lubrication in industrial machines.

Table 1 characterize and established causes of poor parametric analysis of lubrication in industrial machines.

Cause	Description	Percentage Contribution
1. Inadequate Data Collection	Insufficient or inconsistent data on lubrication parameters such as viscosity, temperature, and load conditions.	25%
2. Lack of Real-Time Monitoring	Absence of real-time sensors and monitoring systems for lubrication conditions, leading to delayed response to changes in operational parameters.	20%
3. Nonlinearities in Lubrication	Complex, nonlinear behavior of lubrication systems under varying conditions, which traditional models fail to address.	15%
4. Poor Maintenance Practices	Inadequate maintenance schedules and improper lubrication management, leading to misaligned or degraded parameters.	15%
5. Variability in Operational Loads	Frequent changes in machine load and speed that alter lubrication performance without appropriate compensation.	10%
6. Environmental Factors	External factors such as dust, moisture, and temperature fluctuations that impact lubrication efficiency.	10%
7. Limited Use of Intelligent Tools	Lack of advanced tools such as fuzzy logic or AI-based systems for analyzing and optimizing lubrication performance.	5%

Summary

The table highlights the major causes of poor parametric analysis of lubrication, with inadequate data collection and lack of real-time monitoring systems contributing the largest share. Advanced techniques such as intelligent controllers can address these issues by improving data acquisition, real-time adaptability, and handling nonlinearities in lubrication systems.

To design a SIMULINK model for parametric analysis of lubrication in industrial machines

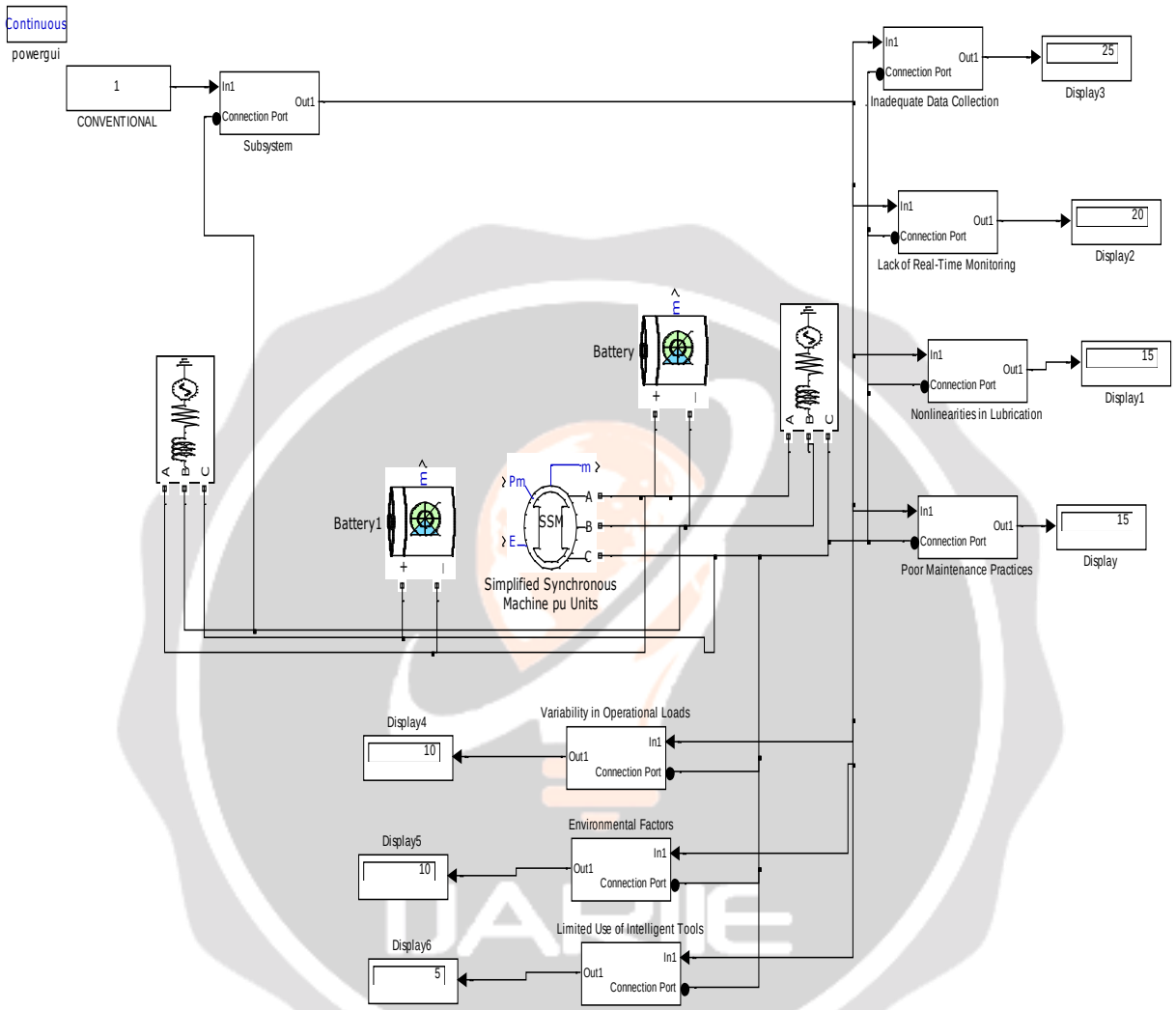

Fig1 designed SIMULINK model for parametric analysis of lubrication in industrial machines

The results obtained were as shown in figures 7and 8

To develop an SVC rule base that will reduce the causes of poor parametric analysis of lubrication in industrial machines.

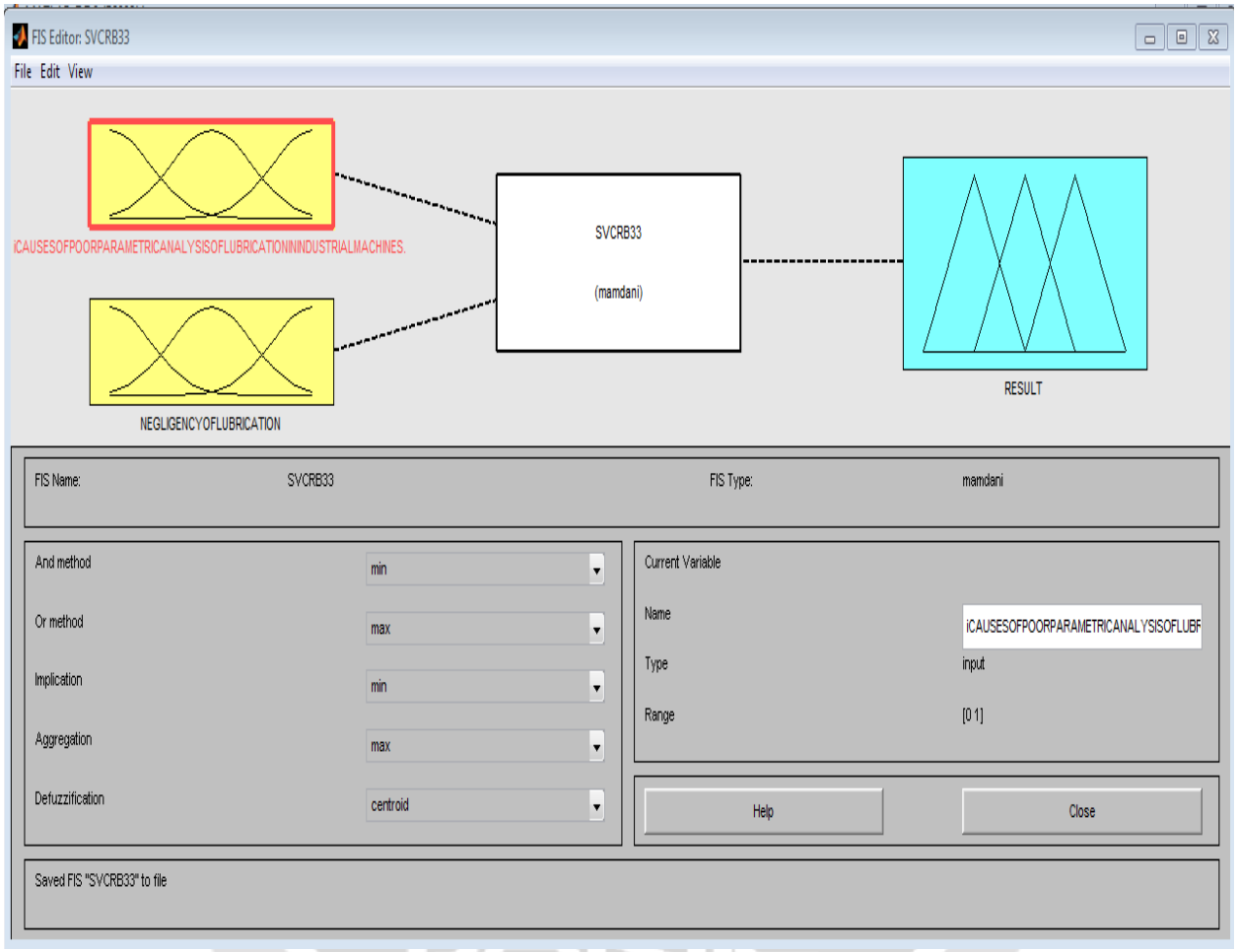

Fig 2 develop an SVC fuzzy inference system that will reduce the causes of poor parametric analysis of lubrication in industrial machines

This has two inputs of causes of poor parametric analysis of lubrication in industrial machines and negligence of lubrication. It also has an output of result.

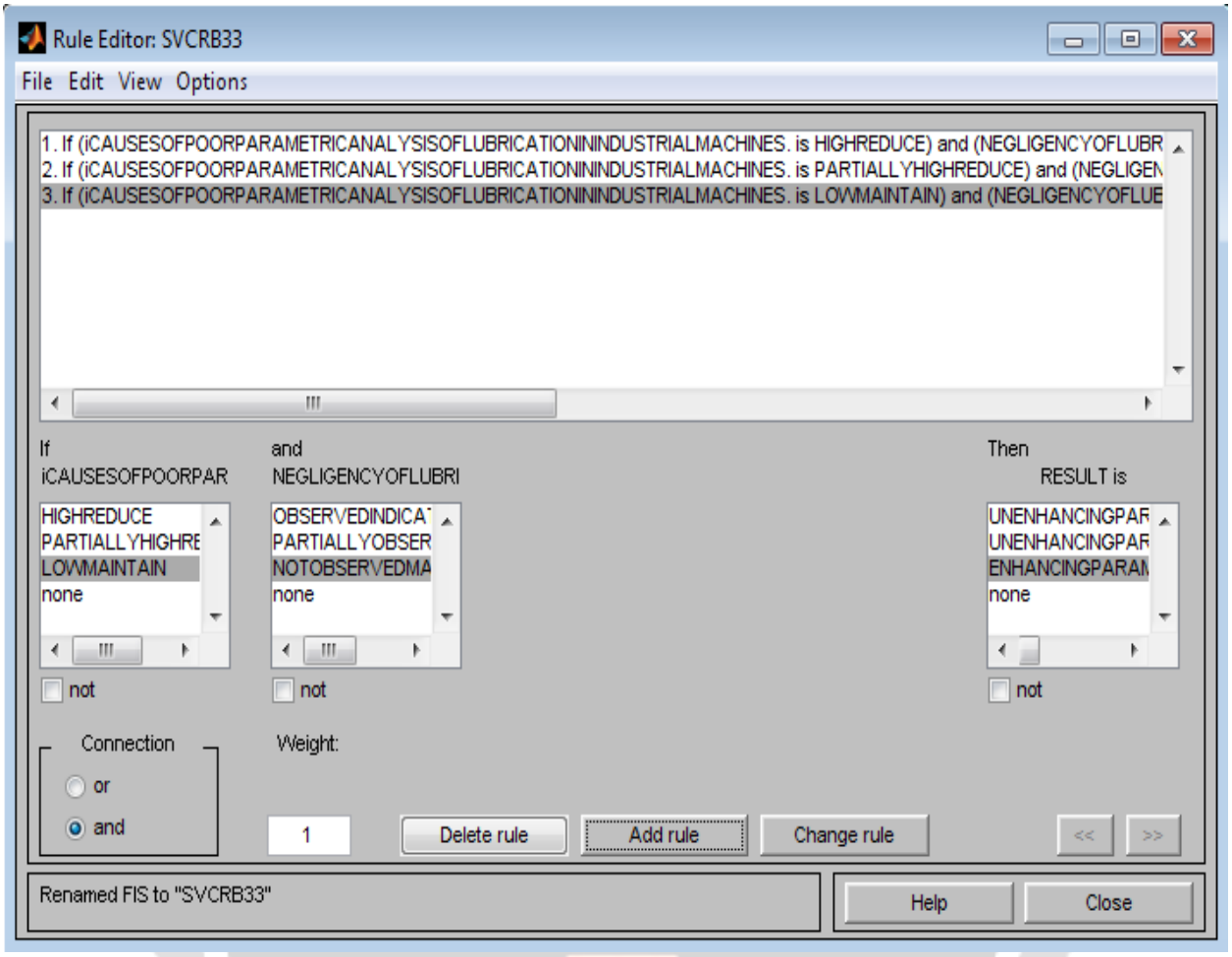

Fig 3 developed SVC rule base that will reduce the causes of poor parametric analysis of lubrication in industrial machines

The comprehensive details of the rules were as shown in table 2

Table 2 comprehensive details of causes of poor parametric analysis of lubrication in industrial machines

1	IF CAUSES OF POOR PARAMETRIC ANALYSIS OF LUBRICATION IN INDUSTRIAL MACHINES. IS HIGH REDUCE	AND NEGLIGENCY OF LUBRICATION IS OBSERVED INDICATE	THEN RESULT ISUN ENHANCED PARAMETRIC ANALYSIS OF LUBRICATION IN INDUSTRIAL MACHINES
2	IF CAUSES OF POOR PARAMETRIC ANALYSIS OF LUBRICATION IN INDUSTRIAL MACHINES. IS	AND NEGLIGENCY OF LUBRICATION IS PARTIALLY OBSERVED INDICATE	THEN RESULT ISUN ENHANCED PARAMETRIC ANALYSIS OF LUBRICATION IN

	PARTIALLY HIGH REDUCE		INDUSTRIAL MACHINES
3	IF CAUSES OF POOR PARAMETRIC ANALYSIS OF LUBRICATION IN INDUSTRIAL MACHINES. IS LOWMAINTAIN	AND NEGLIGENCY OF LUBRICATION IS NOT OBSERVED MAINTAIN	THEN RESULT IS ENHANCED PARAMETRIC ANALYSIS OF LUBRICATION IN INDUSTRIAL MACHINES

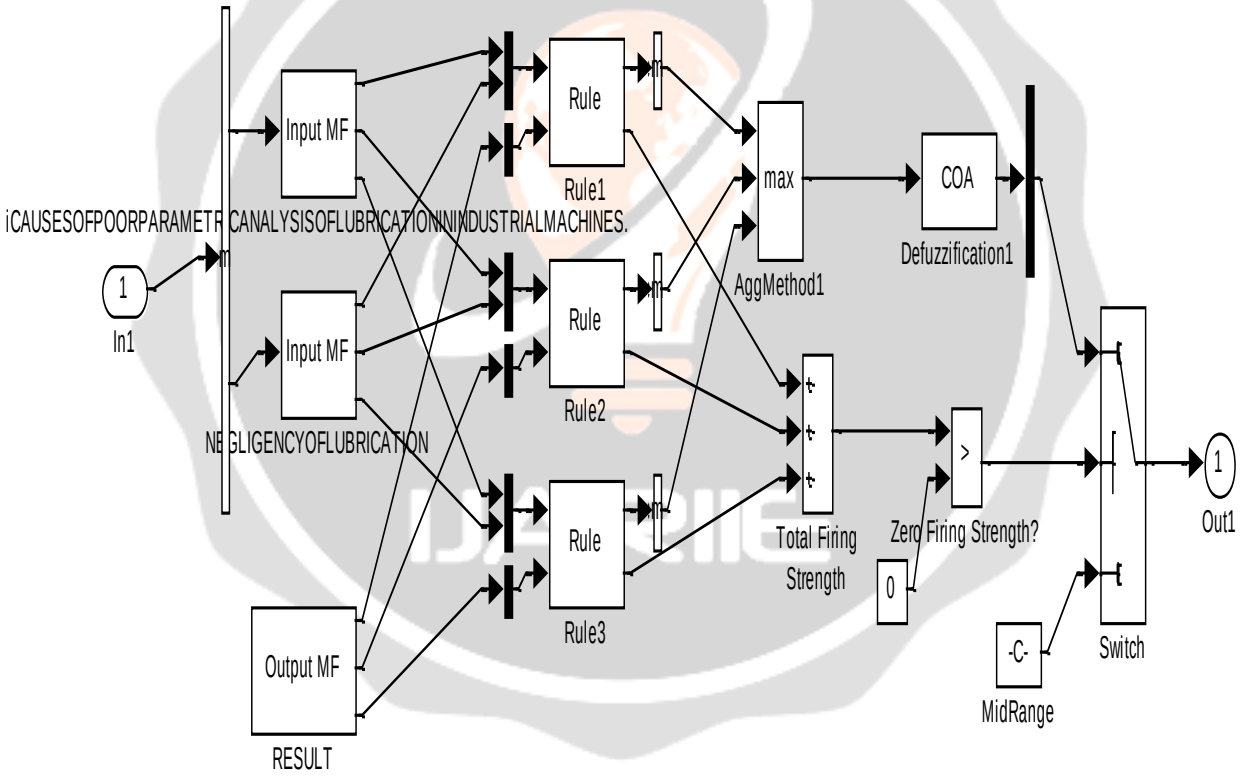

Fig 4 operational mechanism of the rules

To design SVC SIMULINK model

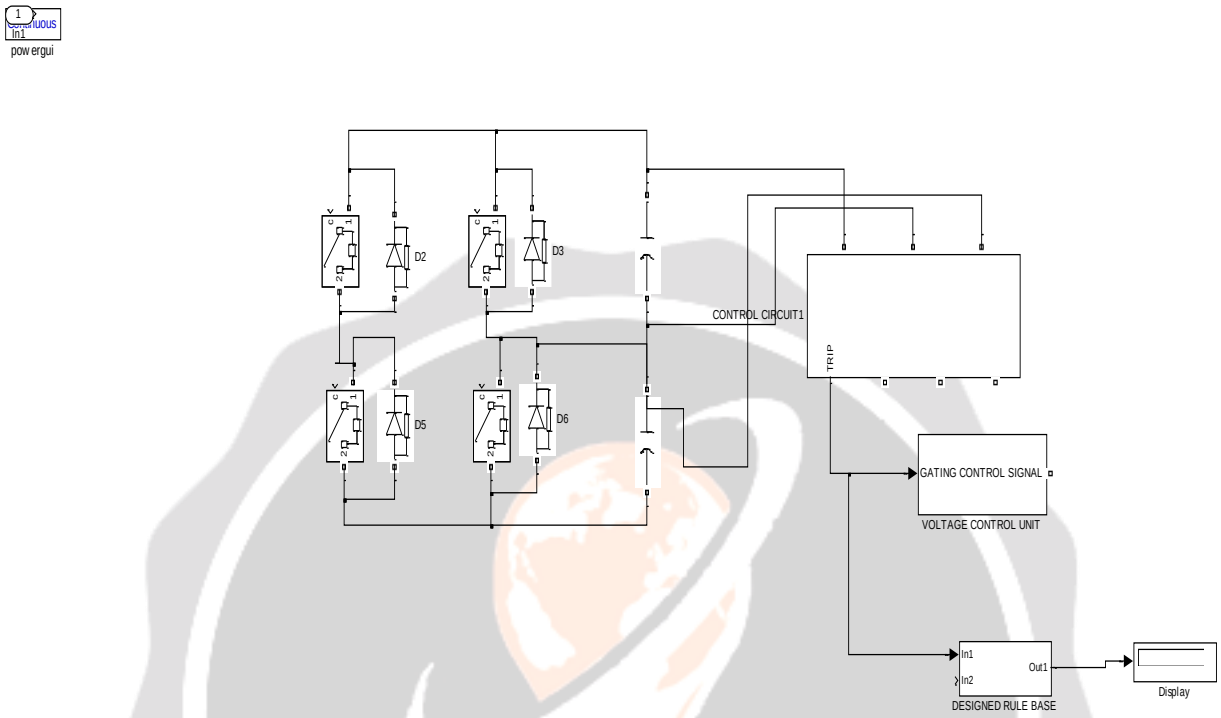

Fig 5 design SVC SIMULINK model

To develop an algorithm that will implement the process

1. Characterize and establish the causes of poor parametric analysis of lubrication in industrial machines.
2. Identify **Inadequate Data Collection**
3. **Identify Lack of Real-Time Monitoring**
4. **Identify Nonlinearities in Lubrication**
5. **Identify Poor Maintenance Practices**
6. Identify **Variability in Operational Loads**
7. **Identify Environmental Factors**
8. **Identify . Limited Use of Intelligent Tools**
9. design a SIMULINK model for parametric analysis of lubrication in industrial machines and integrate 2 through 8
10. Develop an SVC rule base that will reduce the causes of causes of poor parametric analysis of lubrication in industrial machines.
11. Design a SIMULINK model for SVC
12. Integrate 10 and 11
13. Integrate 12 in 9
14. Did the causes of poor parametric analysis of lubrication in industrial machines reduce when 12 was integrated in 9?
15. IF NO go to 13
16. IF YES go to 17
17. Enhanced parametric analysis of lubrication in industrial machines
18. Stop

19. End

To design a SIMULINK model for enhancing parametric analysis of lubrication in industrial machines using fuzzy based STATIC VAR COMPENSATOR (SVC)

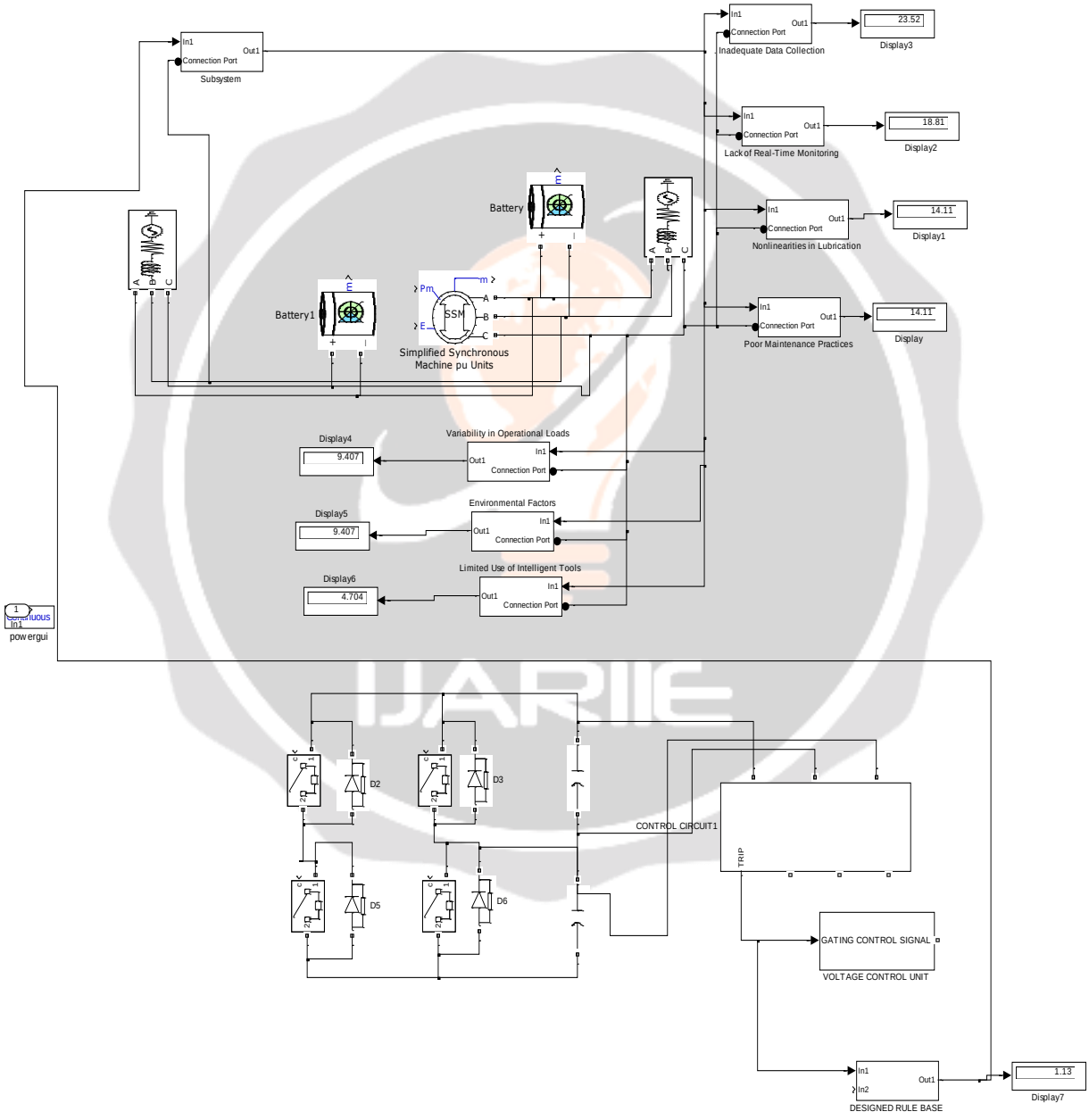

Fig 6 designed SIMULINK model for enhancing parametric analysis of lubrication in industrial machines using fuzzy based STATIC VAR COMPENSATOR (SVC)

The results obtained were as shown in figures 7 and 8

To validate and justify the percentage improvement in the reduction of the causes of poor parametric analysis of lubrication in industrial machines with and without fuzzy based STATIC VAR COMPENSATOR

To find percentage improvement in the reduction of **Inadequate Data Collection** of the causes of poor parametric analysis of lubrication in industrial machines with fuzzy based STATIC VAR COMPENSATOR

Conventional Inadequate **Data Collection** =25%

Fuzzy based STATIC VAR COMPENSATOR **Inadequate Data Collection =23.5%**

%improvement in the reduction of **Inadequate Data Collection** of the causes of poor parametric analysis of lubrication in industrial machines with fuzzy based STATIC VAR COMPENSATOR

Conventional Inadequate **Data Collection -** Fuzzy based STATIC VAR COMPENSATOR **Inadequate Data Collection**

%improvement in the reduction of **Inadequate Data Collection** of the causes of poor parametric analysis of lubrication in industrial machines with fuzzy based STATIC VAR COMPENSATOR=25% - **23.5%**

%improvement in the reduction of **Inadequate Data Collection** of the causes of poor parametric analysis of lubrication in industrial machines with fuzzy based STATIC VAR COMPENSATOR=1.5%

To find percentage improvement in the reduction of **Nonlinearities in Lubrication** of the causes of poor parametric analysis of lubrication in industrial machines with fuzzy based STATIC VAR COMPENSATOR

Conventional Inadequate **Nonlinearities in Lubrication** =15%

Fuzzy based STATIC VAR COMPENSATOR **Nonlinearities in Lubrication =14%**

%improvement in the reduction of **Nonlinearities in Lubrication** of the causes of poor parametric analysis of lubrication in industrial machines with fuzzy based STATIC VAR COMPENSATOR

Conventional Inadequate **Nonlinearities in Lubrication -** Fuzzy based STATIC VAR COMPENSATOR **Nonlinearities in Lubrication**

%improvement in the reduction of **Nonlinearities in Lubrication** of the causes of poor parametric analysis of lubrication in industrial machines with fuzzy based STATIC VAR COMPENSATOR=15% - **14%**

%improvement in the reduction of **Nonlinearities in Lubrication** of the causes of poor parametric analysis of lubrication in industrial machines with fuzzy based STATIC VAR COMPENSATOR=1%

3.0Results and Discussion

Table 3 comparison of conventional and Fuzzy based STATIC VAR COMPENSATOR Inadequate **Data Collection that** causes of poor parametric analysis of lubrication in industrial machines

Time(s)	Conventional Inadequate **Data Collection that** causes of poor parametric analysis of lubrication in industrial machines(%)	Fuzzy based STATIC VAR COMPENSATOR Inadequate **Data Collection that** causes of poor parametric analysis of lubrication in industrial machines(%)
1	25	23.5
2	25	23.5
3	25	23.5
4	25	23.5
10	25	23.5

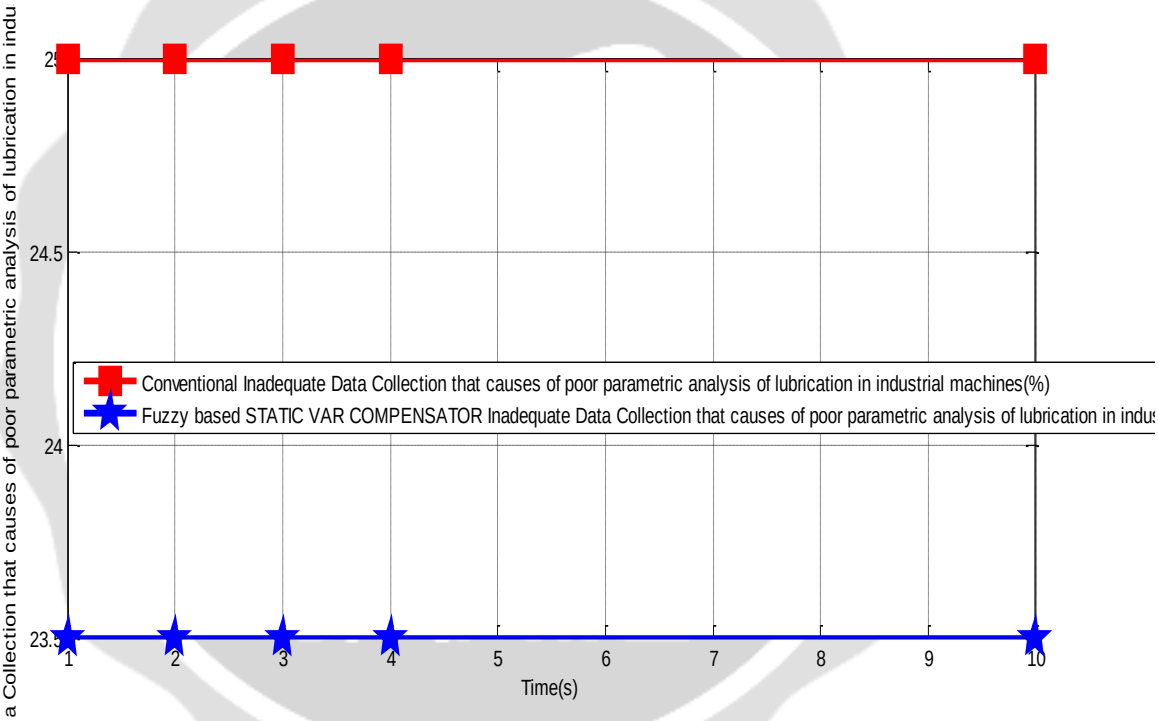

Fig 8 comparison of conventional and Fuzzy based STATIC VAR COMPENSATOR Inadequate **Data Collection that** causes of poor parametric analysis of lubrication in industrial machines

The conventional inadequate **Data Collection that** causes poor parametric analysis of lubrication in industrial machines. On the other hand, when Fuzzy based STATIC VAR COMPENSATOR was integrated in the system, it decisively reduced it to 23.5%

Table 4 comparison of conventional and Fuzzy based STATIC VAR COMPENSATOR **Nonlinearities in Lubrication that** causes of poor parametric analysis of lubrication in industrial machines

Time(s)	Conventional **Nonlinearities in Lubrication that** causes of poor parametric analysis of lubrication in industrial machines(%)	Fuzzy based STATIC VAR COMPENSATOR **Nonlinearities in Lubrication that** causes of poor parametric analysis of lubrication in industrial machines(%)
1	15	14

2	15	14
3	15	14
4	15	14
10	15	14

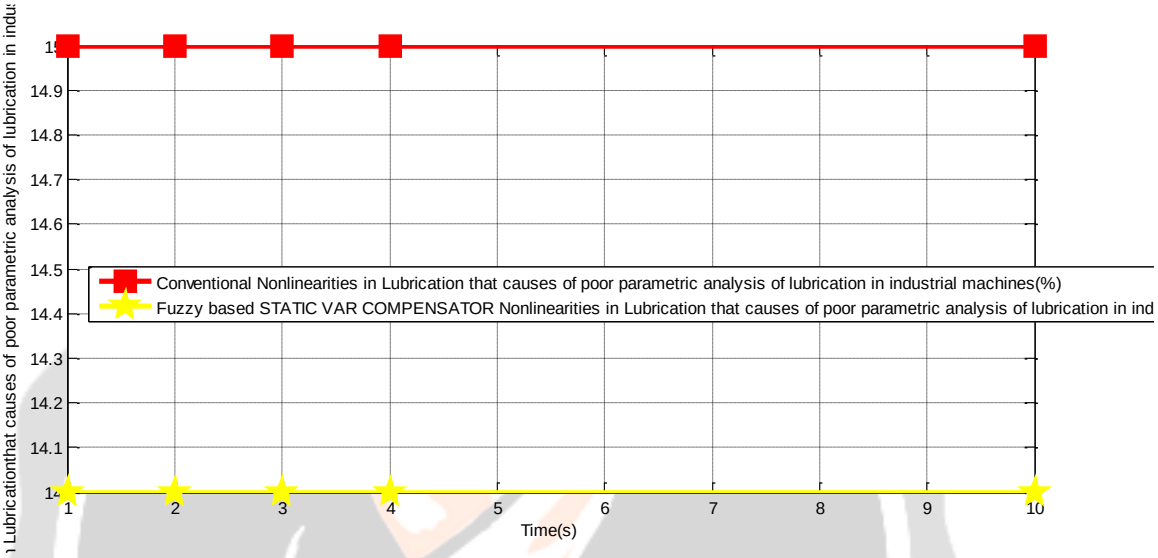

Fig 8 comparison of conventional and Fuzzy based static VAR compensator Nonlinearities in Lubrication that causes of poor parametric analysis of lubrication in industrial machines

The conventional Nonlinearities in Lubrication that causes of poor parametric analysis of lubrication in industrial machines was 15%. On the other hand, when Fuzzy based static VAR compensator **was integrated in the system, it drastically reduced it to** 14%. The percentage enhancement of parametric analysis of lubrication in industrial machines was 1%

4.0 Conclusion

Enhancing the parametric analysis of lubrication in industrial machines using a fuzzy-based Static Var Compensator (SVC) presents a significant advancement in maintaining efficiency, reliability, and longevity of machinery. This approach addresses the limitations of traditional methods by leveraging the adaptive and rule-based decision-making capabilities of fuzzy logic, combined with the dynamic compensation provided by SVC technology. The integration of fuzzy-based SVC enables precise analysis of lubrication parameters under varying operational conditions, effectively managing nonlinearities and uncertainties. This leads to optimized lubrication performance, reduced wear, improved energy efficiency, and minimized downtime, contributing to overall operational cost savings. The results from this study demonstrate that applying intelligent techniques to lubrication management significantly improves the ability to monitor and control critical parameters, ensuring machines operate at their peak performance. Future research should explore the integration of advanced IoT and AI technologies with fuzzy-based SVC systems to further enhance real-time monitoring and predictive maintenance strategies. This innovative approach marks a transformative step toward intelligent industrial machine management, promoting sustainability and operational excellence. The conventional Nonlinearities in Lubrication that causes of poor parametric analysis of lubrication in industrial machines was 15%. On the other hand, when Fuzzy based static VAR compensator **was integrated in the system, it drastically reduced it to** 14%. The percentage enhancement of parametric analysis of lubrication in industrial machines was 1%

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