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Power System Stability Using Multi-Objective Genetic Algorithm NSGA-II

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Abstract: *STATCOM is a source of controllable reactive current used to balance reactive power at power system nodes and manage reactive flow in transmission lines. Most prevalent efficient FACTS stand for Flexible AC Transmission Systems components is the Static Synchronous Compensator (STATCOM), which is frequently modeled as a controlled voltage source for reactive current regulation and increased stability of the power system. To improve the stability of the power grid, a unique robust control strategy for STATCOM controller design has been developed. The suggested scheme is characterized as an optimization problem, and the performance and stability of the controller are assessed using the robustness criteria. To change the controllers' coefficients, the proposed model is applied to each of these control systems, and used controller is a PID controller, The Pareto optimal solution is initially discovered using a modified version of the non-dominance-based genetic algorithm (NSGAII). Due to an increase in load and inadequate growth of the producing and transmission capacity, the operating limitations of a modernized integrated power system are getting tighter. Electricity networks occasionally experience small oscillations.*

Keywords: Power system Stability, STATCOM, GTO, NSGA

I. INTRODUCTION

The main requirement for economic expansion is electrical energy. Large-scale industrialization a considerable rise in the need for electrical energy as a result. Due to the deregulation of the electric power system and the surge in demand, the contemporary power system functions under extremely stressful conditions. This causes a number of issues with how power systems operate and are controlled. The power utilities are very concerned about the economics of electricity generation. As a result, new technology is constantly needed by the power utilities to address their issues. In essence, an integrated power system is made up of several crucial parts. They are the loads, the transmission lines, and the generating units. There may be some disruptions during the functioning of the generators, for instance prolonged periodic or oscillating speed fluctuations in the generator torque input. Other components of the connected power supply may be impacted by voltage or frequency fluctuations brought on by these disruptions. The electricity system might also be disturbed by external events like lightning. All of these alterations are referred to as defects. The generators lose synchronism when a failure happens.

The stability of the system is impacted when the power system has a malfunction. The machines connected to the system may be harmed when such instability persists for a long time. Therefore, it is crucial to quickly restore the system to its original state. Power electronic gadgets are used to create this condition [1]. FACTS technology is a useful approach that can modify the properties of the power systems to improve regulation of power flow, gearbox capabilities, and oscillation damping [2]. These tools are actually used to address the control limitations of electrical gearbox systems. Switches for FACTS devices that function quickly in solid state have been developed in the modern era to help electrical grids perform better under transient and dynamic conditions. There are two generations of FACTS devices. Reactive power is managed in the initial generation using conventional switch thyristors and capacitor banks. Some of the first-generation FACTS devices are the Static VAR Compensator (SVC) and the thyristor controlled series capacitor (TCSC). One of the FACTS devices from the second generation, STATCOM is made using bi-directional semiconductor switches like GTO and is utilized for reactive parallel power adjustment depending on Voltage Source Converters (VSC). Reactive power shared by a transmission line and a STATCOM is able to increase system voltage by adjusting the STATCOM voltage. Creating a practical for this equipment's control system can supply the proper status to dampen and regulate the oscillations in addition to regulating the voltage. [3]. Since, STATCOM has the ability to momentarily exchange active power with the system; it exhibits better behavior than the SVC. A voltage source converter coupled to a DC capacitor creates a programmable AC voltage source behind a transformer leaking reactance as the fundamental working concept of a STATCOM. The STATCOM is typically made to offer quick voltage management and to improve inter-area oscillation damping [4]. It is common knowledge that the stability of a SMIB system is becoming increasingly significant.

II. THE POWER SYSTEM MODEL

A Third-order system SMIB model through a STATCOM that is positioned at the midpoint of using a step-down transformer on a transmission line is used to model the power system in order to analyze the stability of the power system. As a result, it is assumed that both the input mechanical force and the amplitude behind the SG's voltage momentary reactor are constant. The next three sections of this chapter go into great detail about system modeling. After discussing the dynamic modeling of the system's component sections, SG and STATCOM, the linear model for the system is presented [7].

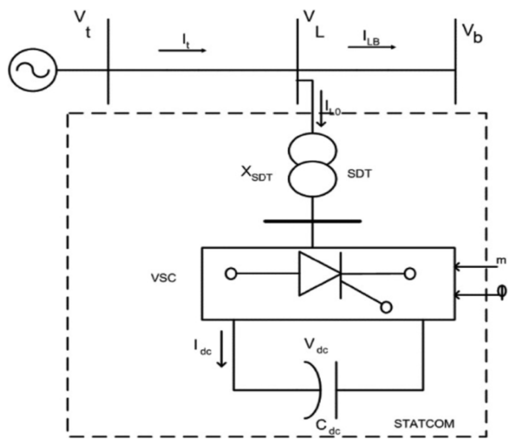

Fig.1. SMIB system with STATCOM single-diagram

The generator is depicted by a second-order model made up of the electromechanical swing equation and the generator internal voltage equation. The dynamic equations for the SG rotor are explained as

$$\delta = \omega_0$$

$$\omega = \frac{(P_m - P_e - D_\omega)}{M}$$

The STATCOM controller output is written as,

$$\Delta u = -C_v \Delta V_m + C_\omega \Delta\omega$$

III. STATCOM

A shunt-connected reactive compensation device used on transmission networks is referred to as a static synchronous compensator (STATCOM). A static synchronous compensator (STATCOM) is a quick-acting tool that may supply or absorb reactive current, controlling the voltage at the point of grid connection. It creates a voltage-source converter with power electronics that can provide or drain reactive AC power to a network of electrical outlets [5]. Other passive reactive power components, such capacitors and inductors (reactors), can be replaced with STATCOMs. STATCOMs can supply and consume both capacitive and inductive vars, have a changeable reactive power output, and alter their output in terms of milliseconds. A member of the FACTS family, a STATCOM or Static Synchronous Compensator is primarily used in long-distance transmission lines, power substations, and heavy industries where voltage stability is of utmost importance. The force-commutated power electronics used by the shunt connected STATCOM to manage the active and reactive power flow in the system includes GTO, IGBT, etc. STATCOM is a switching converter VAR generator that is shunt linked. With operational voltage-current characteristics as low as 0.15pu, it can be a voltage or current source converter [8]. By adjusting the amplitude of the STATCOM's output voltage, reactive power can be added to or removed from a power system. By adjusting the STATCOM's inverter output voltage, real power can be added to or subtracted from a system [9]. The system's real power is increased when a suitable energy storage component is connected across the DC capacitor. In essence, STATCOMs are used for load balancing, harmonic compensation, and voltage regulation, among other things. STATCOM's basic block diagram is as shown in fig 2.

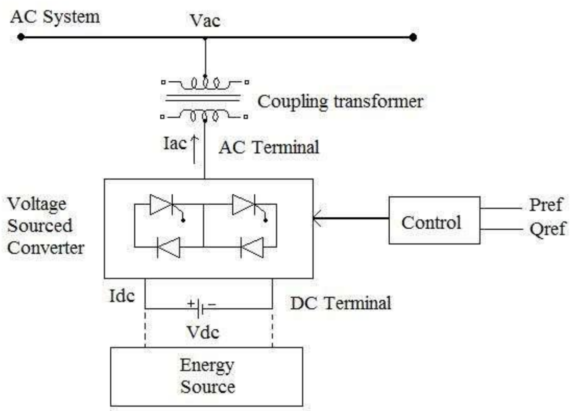

Fig. 2. Functional Block Diagram of STATCOM

Recently, a new gadget known as the Static Compensator (STATCOM) was created in response to the availability of high power gate-turn-off thyristors (GTO). The STATCOM is a piece of second generation voltage source inverter-based FACTs equipment. Static Var Compensator (SVC) in its
advanced form, STATCOM, uses self self-commutating devices like GTOs. However, STATCOM's
operational and functional features differ from those attained through SVC.

CONTROLLER DESIGNING

We'll talk about the controller designing approach. As was already indicated, all of The controllers of the suggested controllers with PID controller structures. A novel robust control method is used to design these controllers. The proposed model reduced power system oscillations after significant disruptions, each abrupt Operating-system change circumstances, and every mistake brought on by failing to take into account the dynamics of the system. General Control Configuration (GCC) upon which the controller is designed. In this section remaining paragraphs provide a detailed explanation of the method used to create the controller.

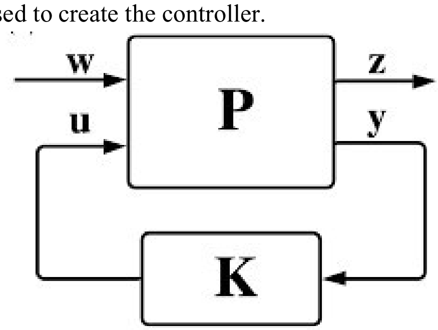

Fig. 3. General control configuration

$$x = Ax + \hat{B}_1W + B_2W$$

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Where, u and B_2 consist of the input vector, which is a control law that we intentionally apply to the system and the matrix of the inputs system coefficients. Also, W is the input vector that has an undesirable application, such as disturbance.

IV. MULTI-OBJECTIVE GENETIC ALGORITHM NSGA-II

The aim of multi-objective optimization is to identify one or more optimal solutions that would produce values for each of the objective functions that the decision-maker finds acceptable.

Therefore, a Decision Support System can include multi-objective optimization to help a practitioner make decisions [12]. Multi-objective optimization problems have been approached in a variety of ways, from simply integrating the objectives into one to using game theory to coordinate the relative value of each objective. However, unlike a set of good trade-off solutions from which the decision maker can select one, these traditional methodologies can only uncover one optimal answer in a single simulation run [13].

Rosenberg first made suggestions about the potential of Genetic Algorithms (GAs) in multi objective optimization in the 1960s. Engineering optimization design issues with many objectives can be successfully solved with a multi-objective genetic algorithm. Numerous traditional and enhanced multi-objective genetic algorithms (MOGA) have been presented by academics. The findings demonstrate that the NSGA-II algorithm performs more comprehensively, particularly in the areas of distribution and operating efficiency [14]. It is essential to increase optimization efficiency for complicated multi-objective optimization issues, such as multi-objective and interdisciplinary design optimization. NSGA-II, with its increased relative efficiency, is a superior option for solving these types of problems. The first section of this paper briefly describes the NSGA-II computation procedure in order to increase efficiency. A more effective multi-objective constraint genetic algorithm based on Pareto and hierarchical sorting is proposed in the second part, where the

NSGA-II is enhanced through the construction of non-dominant sets, the sorting of infeasible individuals, and the calculation of crowding distances of individuals in the same sorting set. Three examples are provided to validate the algorithm in the third section.

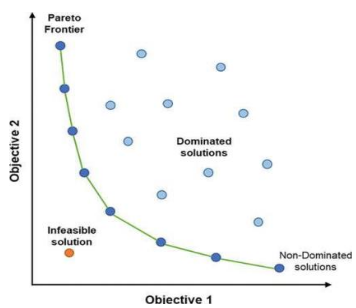

Fig.4. Pareto front obtained by solving the proposed problem

V. SIMULATION STUDY AND RESULT ANALYSIS

The following are the obtained initial conditions, the required parameters are written to calculate these values given in the below Table1

Table 1. Initial Conditions

Parameters	*Value*
Iao	*0.8657*
$Ø_0$	-17.8085^0
Eqo	*2.2801*
δo	47.5111^0
Ido	*0.7866*
Iqo	*0.3615*
Vdo	*0.5928*

Vqo	*0.9901*
Efdo	*0.2329*

The parameters of the linearized model are determined in tabular form using the test system given.

Table 2. Parameter Constants

Parameters	*Value*
K_1	*1.3315*
K_2	*1.1433*
K_3	*03071*
K_4	*1.6635*

Simulation Model of Speed Controller

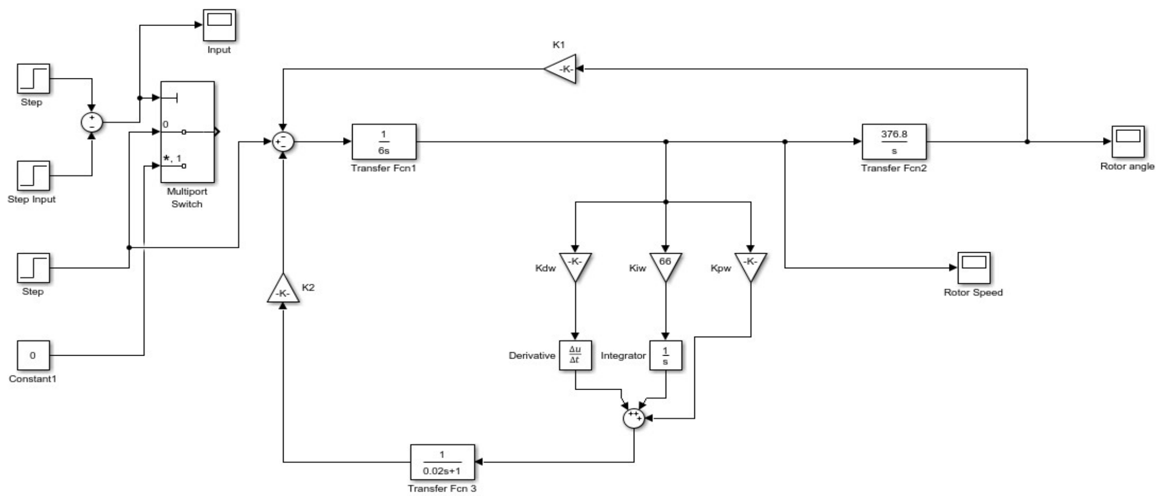

Fig.5. Simulink model of Speed controller Scenario 1

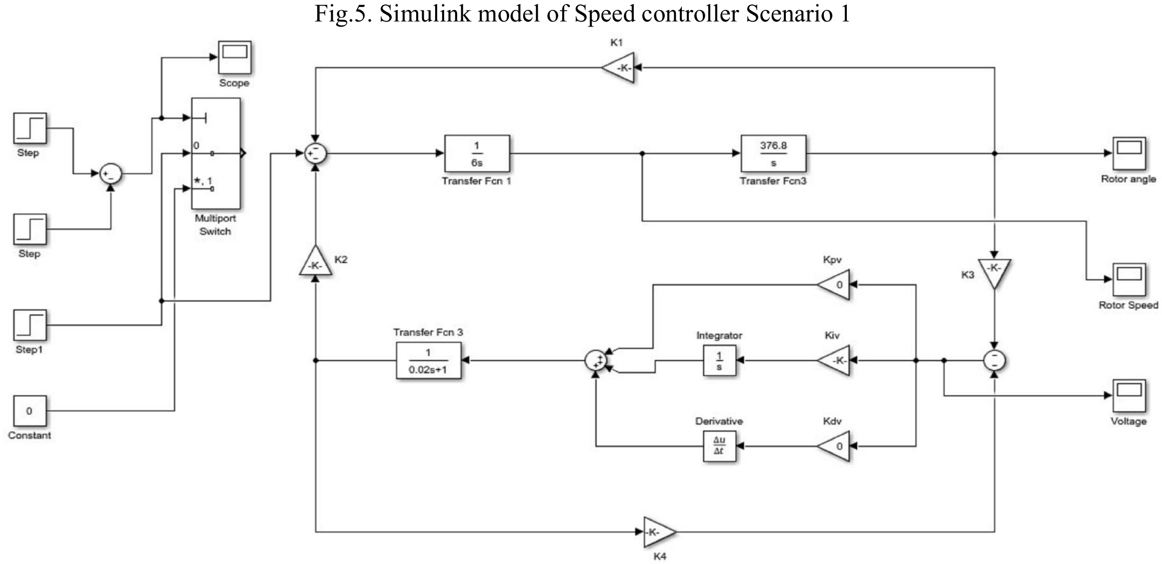

Fig.6.Simulink model of Voltage controller Scenario 2

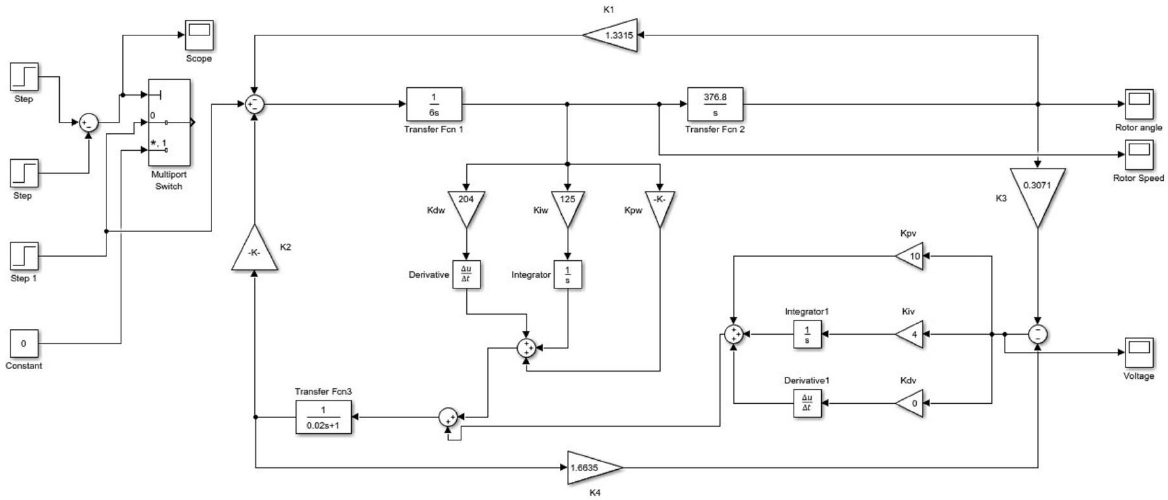

Fig. 7 Simulink model of Robust control system (Scenario 3)

Table 3 displays achieved controller coefficients for various scenarios. The derived coefficients for the speed and voltage control loops, respectively, are represented by rows 1 through 3 and 4 through 6. In S1 and S3, the NSGAII algorithm suggests a Proportional Integral Derivative (PID) controller for the speed control loop. Also obtained as I and PID is the suggested controller for the voltage loop for S2 and S3.

Table 3 The calculated controller coefficients for various scenarios

Operator Coefficient	Situation 1	Situation 2	Situation 3
K_{pw}	155	0	477.1
K_{iw}	59	0	115
K_{dw}	45.5	5	194.7
K_{pv}	0	0	3
K_{iv}	0	33.2	2
K_{dv}	0	0	0.001

Simulation Result of Robust control system

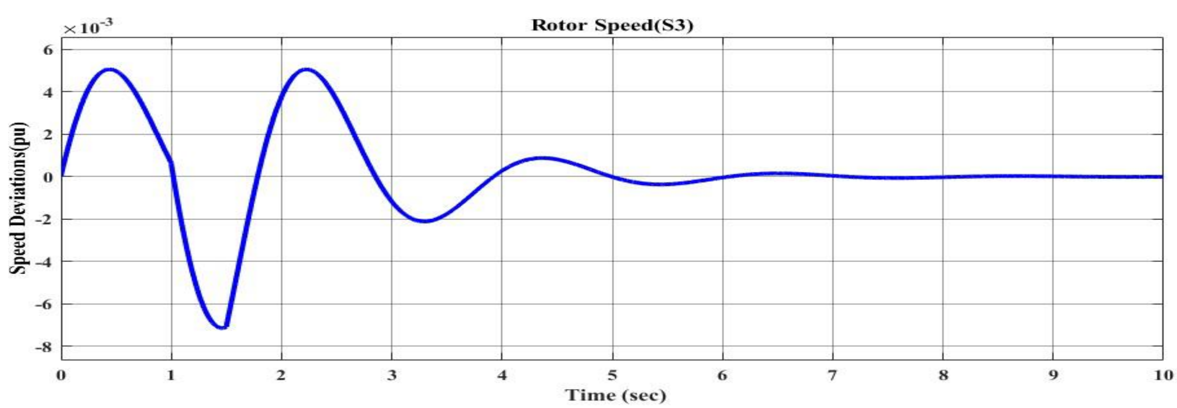

Fig. 8. Speed deviations after applying disturbance (scenario 3)

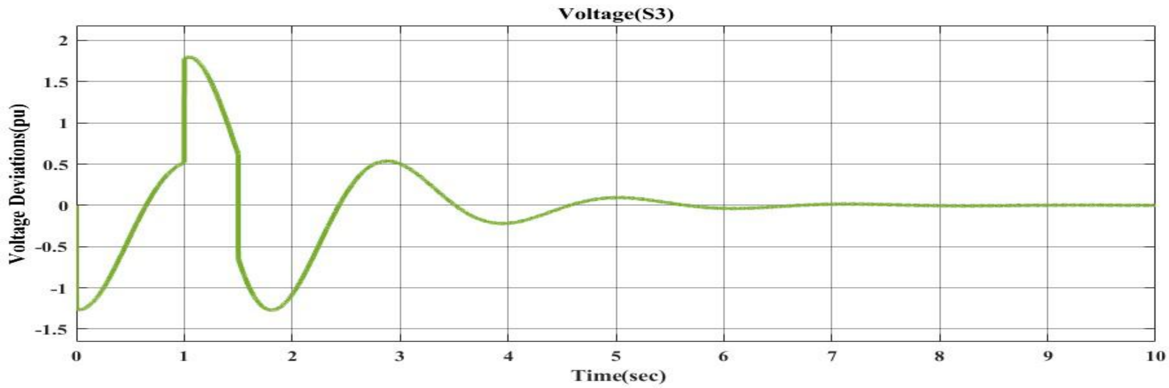

Fig. 9. Voltage deviations after applying disturbance (scenario 3)

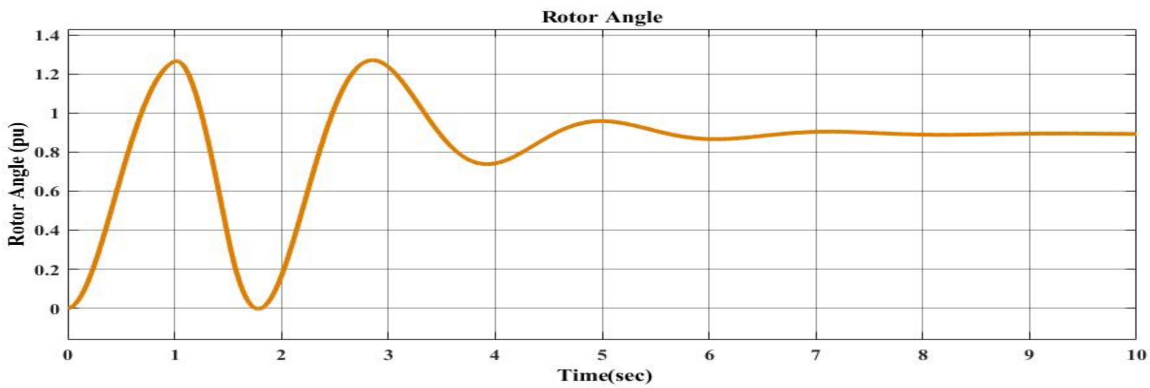

Fig. 10. Rotor angle deviations after applying disturbance (scenario 3)

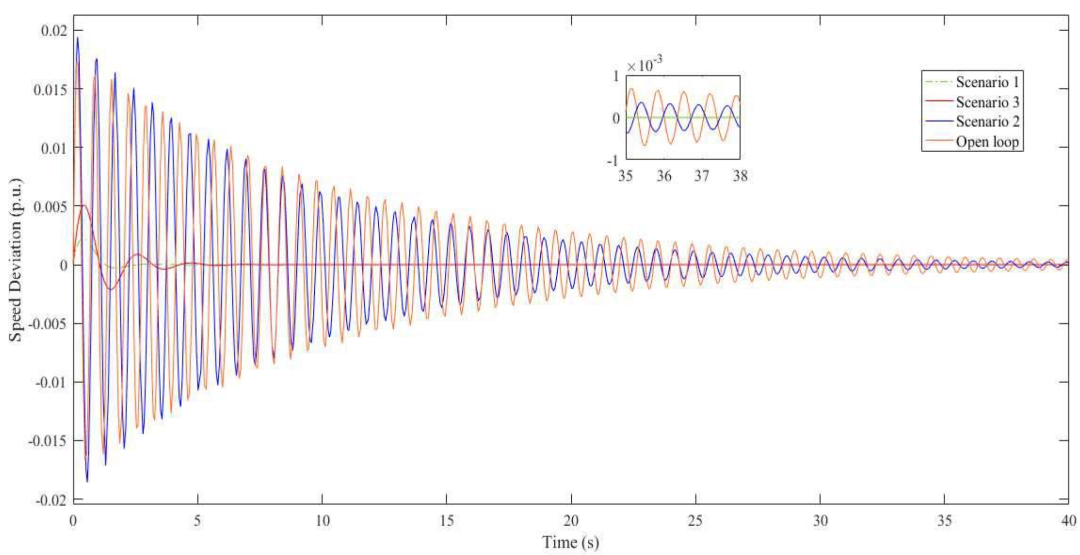

Fig. 11. Speed magnitude deviation with robust STATCOM controller with different Scenario

VI. CONCLUSION

A new technique for creating reliable STATCON damping control techniques controllers in power systems is provided. In this case, we employed three PID controller-based control systems to increase oscillations in speed and voltage are dampened, and the stability of the power systems. A multi-objective genetic algorithm called NSGA-II was employed, to tune the suggested controller. We saw that the system's stability as well as damping had risen greatly after utilizing a strong STATCOM controller. The findings showed that S2 performed significantly the voltage magnitude deviations damping is improved, whereas S1 had a notable influence on the speed magnitude deviations damping. It has been discovered that the sturdy design is particularly efficient for a variety of power system operating circumstances.

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