Design of Optimal Controller For A Multi-Area Low Inertia Microgrids System

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ABSTRACT: Microgrids system dynamics contain less inertia than renewable resources do. Currently, a microgrid system with a significant amount of RES is needed. The RES provides a reliable, inexpensive, and clean active power supply to the system. Future distribution networks must incorporate renewable energy sources. The unpredictable nature of the demand as well as the power generated by renewable resources like wind and solar are further characteristics of such networks. Conventional power flow systems or activated distribution networks like microgrids might not be suitable. Maintaining the frequency stability of emerging essential smart grid building pieces like interconnected microgrids is a major challenge. It is possible to provide a significant stability index for frequency management in the power networks. A microgrid is a tiny power grid that can run by itself or in cooperation with other tiny power grids. Any small-scale local power station that has its own generating and storage resources and contains clear limits can be termed a microgrid. Microgrid is a group of interconnected loads and distributed energy resources that behave as a single controllable entity with respect to the grid. Frequency is defined as the quantity of waves passing a specific place in a predetermined amount of time. This project focuses on multi-area low inertia microgrid frequency regulation. Among the many different energy sources are wind, solar, and biodiesel. Batteries and ultracapacitors are employed as storage devices. Independent multi-area micro grid system based on DC lines. We utilise the Fractional Order Proportional Integral Derivative (FOPID) for the frequency controller. To find the best controller parameters, the TLBO (Teaching Learning Based Optimisation) technique is used. Furthermore, the microgrid system analyses the effects of ES units and DC links across all areas.

KEYWORDS: Microgrid , Frequency, generation systems , DC Links, Tie-line, TLBO, FOPID, Modelling

I. Introduction:

Electric power has played a crucial role in the growth and development of technology throughout history. Energy consumption has significantly increased in the power sector as a result of ongoing population growth and technological advancement. Historically, the energy sector relied on non-renewable resources, but because of their scarcity and unfavourable effects, attention is now being given to the use of renewable energy sources (RES). In addition to being practical substitutes for conventional energy sources, renewable energy sources are also environmentally friendly. Since technology has been advancing steadily in recent years, we are now able to use renewable energy sources extensively. The amount of electrical energy that is currently needed is tremendous, and the amount of energy produced utilising only a few renewable resources is insufficient.

The task of keeping the frequency of the system within the tolerance limitations becomes challenging due to the over-penetration of renewable energy sources. For the microgrid-based system to function dependably, the generated power must be sufficient to cover the required load as well as system losses. Microgrids rely on renewable energy sources that are erratic and have little system-wide inertia. Advanced control strategies must be used in order to guarantee a consistent supply while minimising system frequency variability. It is essential to develop a successful balancing scheme for management due to the irregular variations in generation or loads.

These micro-grids not only give electricity to rural places where a centralised electrical power system would be inefficient, but they also aid in reducing fossil fuel emissions by harnessing clean energy. Additionally, they support the system's dependability and resilience. Microgrids function in either an islanded mode or a grid-connected mode depending on the level of generation. Microgrids that use renewable energy have shown to be effective in supplying the growing demand while having the least negative environmental impact. The addition of RES to the power grid has also promoted consumer involvement in the process of producing electricity. Because they have lower maintenance and operating costs, these renewable energy sources are advantageous for the energy sector. The sole important limitation is the RESs' sporadic nature, which degrades their quality of power delivered. Furthermore, the inconstancy of practical loads, as well as the inherent inability of RESs to sustain frequency variation, has an impact on the nature of the supply.

The system is typically coupled with power converters, limiting its ability to balance. The reliability of RES performance was examined. It was determined that interconnecting renewable sources would improve the system's reliability and voltage profile. Although the RES forming an interconnected system is beneficial in many ways, it also results in a weak grid with instability in its response to disturbances. One of the primary causes of instability is microgrids' lower inertial response when compared to conventional power systems. For example, a solar photovoltaic plant has no significant inertial response, nor does the power system's variable speed wind energy conversion response. As a result, the use of renewables in place of traditional energy sources,

while advantageous in many scenarios, has an impact on the inertial response of the entire power system. The increased penetration of RESs reduces the power system's reserve capacity. This, in turn, reduces the controllability of generation units, resulting in overall system frequency deviation.

Modelling Of Micro grid:

Wind Power Generation System:

The current wind speed has a significant impact on the output of a wind turbine. A wind energy generator has a number of non-linearities associated to it, including the ability to handle frequency fluctuation and adjust pitch angle in response to wind speed.

Due to the pitch control's variation in output wind power between zero and rated power, the system is non-linearly constrained. One possibility is to create a first-order system model of the wind power producing system.

$$G_{wg} = \frac{K_{wg}}{s\tau_{wg}+1};\ K_w = 1,\ T_w = 1.5s$$

Bio Diesel Generation System:

A conventional engine running on agricultural extracts, either in their purest form or as part of a blended fuel, is essentially what makes up a biodiesel generating system. In one of their most recent research, the authors illustrated the efficient combustion and emission properties of a butanol isomer blended biodiesel generated from safflower extracts. The effort has surely pushed the adoption of this environmentally beneficial source in place of diesel. The power produced by a biodiesel generating system is directly determined by the inlet valve and engine operation, and its transfer function is defined as

$$G_{bd} = \frac{K_v K_e}{(s\tau_v+1)(s\tau_e+1)};\ K_e = 1,\ T_e = 0.5,\ K_v = 1,\ T_v = 0.05s$$

Battery Energy Storage System:

A battery energy storage device may successfully help with the stabilisation of device dynamics. A battery unit works effectively for supplying the system because renewable energy sources are utilised and because of its cyclical unpredictability. The utilisation of the battery energy storage devices is supported by their improved energy density and quicker response times. The extra power produced by renewable sources is used to meet demand for electricity and to charge storage devices when renewable energy sources are in short supply. The transfer function model is as follows:

$$G_{bs} = \frac{K_{bs}}{s\tau_{bs}+1};\ K_{bs} = 1,\ T_{bs} = 0.1$$

Solar Photo Voltaic System:

A battery energy storage system could be a useful aid in stabilising gadget dynamics. A battery unit functions effectively for feeding the system due to the usage of renewable energy sources and the temporal unpredictability of those sources. The battery energy storage devices also assist their utilisation with improved energy density and quicker response times. When renewable energy sources are scarce, the extra energy they provide is used to meet demand for electricity as well as to charge storage devices. The transfer function model looks like this:

$$G_{pv} = \frac{K_{pv}}{s\tau_{pv}+1};\ K_{pv} = 1,\ T_{pv} = 1.8s$$

Bio Gas Generation System:

The method generates energy using biogas. The proposal calls for the creation of biogas, which can be used to power a gas turbine engine and is normally produced from biodegradable waste. The report's authors assert that the operation of a turbine, a combustion unit, and a gas input valve is what generates the electricity. The linearized transfer function model looks like this:

$$G_{bg} = \frac{K_{bg}}{s\tau_{bg}+1};\ Kbg=1,\ Tbg=0.2s$$

Ultra Capacitor Storage System:

An ultracapacitor unit performs the crucial task of absorbing and supplying electricity into the system. It is an electrochemical device, one of the newest devices made. A potassium hydroxide electrolyte and a set of porous electrodes have a larger surface area than a conventional capacitor. Its higher specific energy and quicker charge rate make it a better battery replacement.

It also offers a longer operational lifetime. An example of an ultracapacitor unit model is

$$G_{uc} = \frac{K_{uc}}{s\tau_{uc}+1};\ K_{uc} = 1;\ \tau_{uc} = 0.2$$

Archimedes Wave Energy Conversion (AWEC):

In an electrolyser, water is split into hydrogen and oxygen to produce the basic components of fuel cells. The electrolysis process uses the excess energy generated by the power system, which is primarily driven by wind and solar energy generators, to store the energy. The transfer function of the aqua electrolyser system is as follows:

$$G_{ae}=\frac{K_{ae}}{s\tau_{ae}+1} K_{ae} = 1;\ \tau_{ae} = 0.3$$

Diesel Generation System:

A generator powered by diesel is also a part of the constructed microgrid system. The diesel engine producing system is imitated using the governor and droop concept. The transfer function offered is

$$G_{dg}=\frac{K_g}{s\tau_g+1}\times\frac{K_t}{s\tau_t+1} K_g = 1;\ \tau_g = 0.08, K_t=1;\tau_t = 0.4$$

In which the governor and the turbine model are each represented by a function.

Super Conducting Magnetic Energy Storage System:

In magnetic energy storage devices, a magnetic field created over a superconducting coil is used to store energy. It responds quickly, has more power density, and lasts longer between cycles. To keep the superconducting coil below the threshold superconductivity temperature, the gadget has a cooling mechanism. When current (I) flows through the coil, the magnetic field is created depending on the coil's selfinductance (L). The energy input is given as,

$$E=\frac{1}{2}\times LI^2$$

The power output of the system is a time integral of the earlier energy relation. In addition to the cooling system and the superconducting coil, the system has a power conditioning system that provides the stored energy. The SMES is renowned for having an excellent power stability storage system. The system is expressed as a first-order transfer function as follows:

$$G_{sm} =\frac{K_{sm}}{s\tau_{sm}+1} K_{sm} = 0.98, \tau_{sm} = 0.3$$

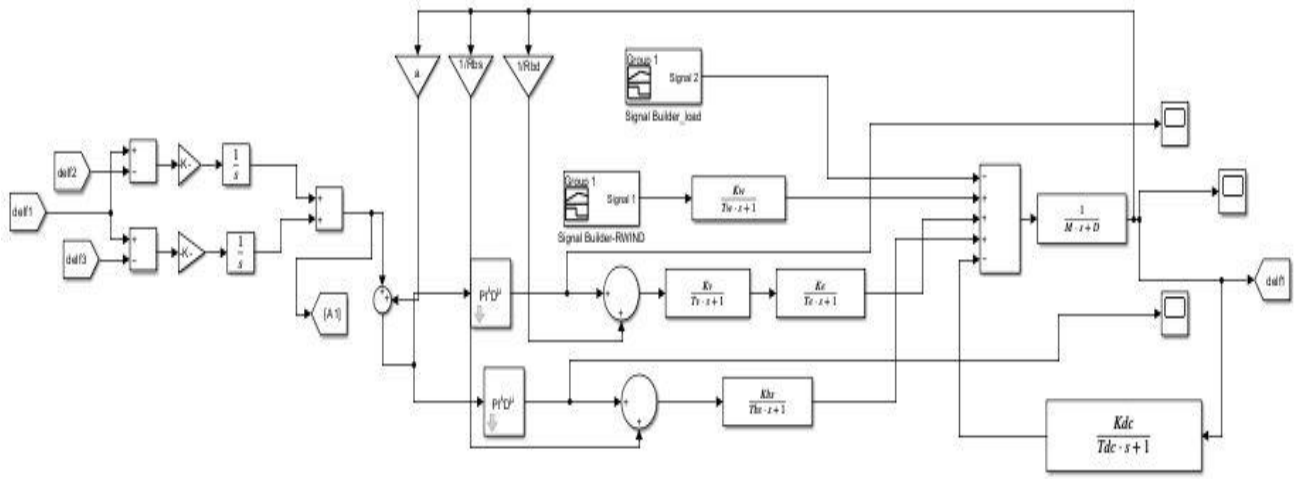
CONTROLLERS:

FOPID Controller:

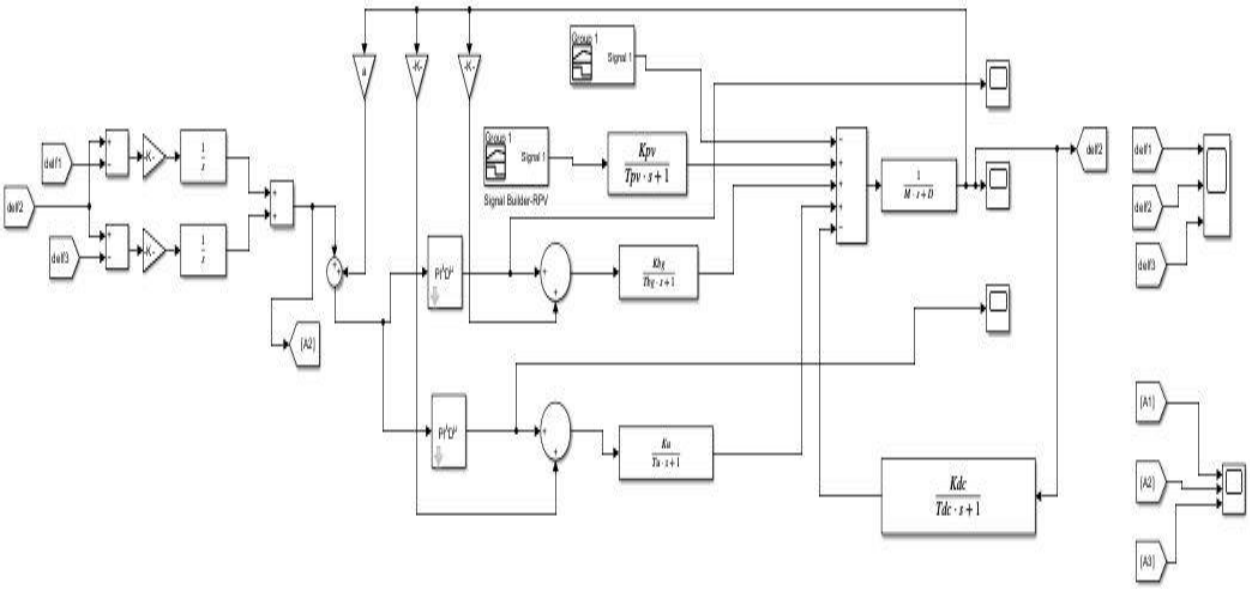
Mathematicians who study fractional-order calculus work with derivative integrals from non-integer orders. In other words, it is a generalisation of classical calculus that results in ideas and methods that are comparable but have a far broader range of applications. Fractional calculus was rediscovered by scientists and engineers two decades ago, and it is now being used in a growing variety of domains, particularly control theory. The development of efficient techniques for the differentiation and integration of non-integer order equations has contributed significantly to the success of fractional-order controllers, which is without dispute. The last few years have seen a lot of interest in fractional-order proportional-integral-derivative (FOPID) controllers from both an academic and an industry perspective. In fact, they provide the controller more freedom in theory.They differ from standard PID controllers in that they have five parameters to choose from instead of just three. However, this also suggests that the controller's tuning may be much more difficult.

IMULINK MODELS:

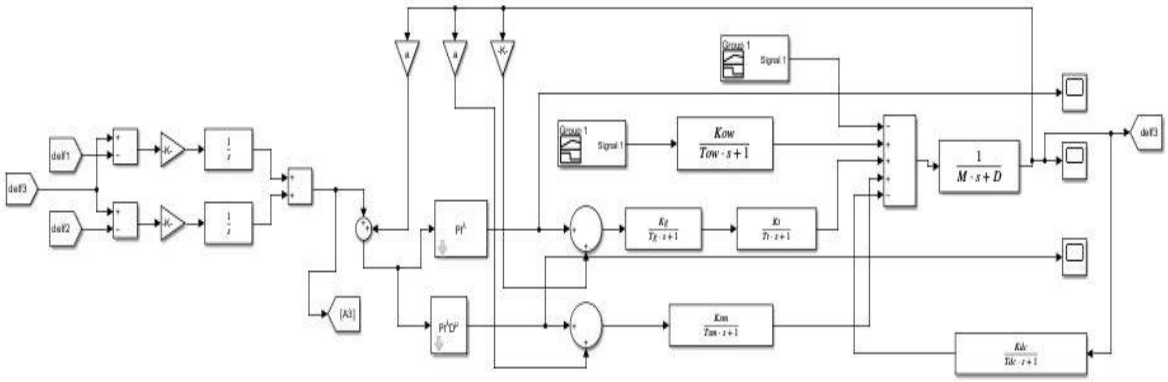
Microgrid 1 using FOPID Controller:



Microgrid 2 using FOPID Controller:



Microgrid 3 using FOPID Controller:



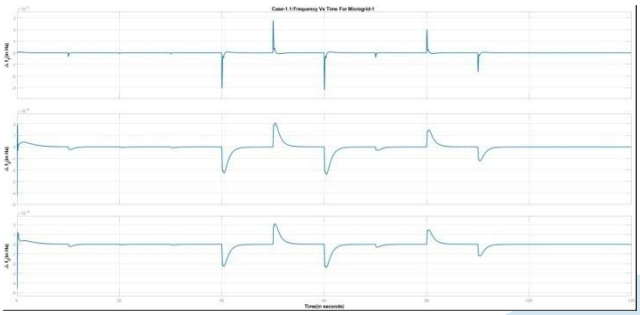
Controller Parameters:

Microgrid	FOPID	Kp	Ki	Lambda	Kd	μ
Microgrid-1	Controller-1	-7.6124	-4.3344	0.99	-1.3694	0.95
Microgrid-1	Controller-2	-12.3753	-23.2648	0.98	-0.4788	0.90
Microgrid-2	Controller-1	-10.7284	-14.7278	0.93	-1.2403	0.97
Microgrid-2	Controller-2	-96.4827	-1058.4614	0.84	-2.1055	0.93
Microgrid-3	Controller-1	-4.7911	-0.8123	0.99	0	0
Microgrid-3	Controller-2	-76.1942	-256.7283	0.89	-5.4151	0.95

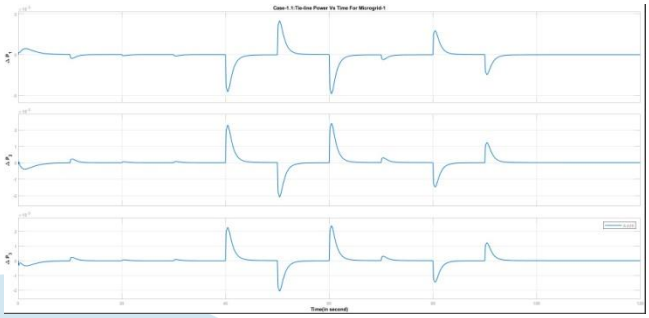
Graphs:

Change in Load:

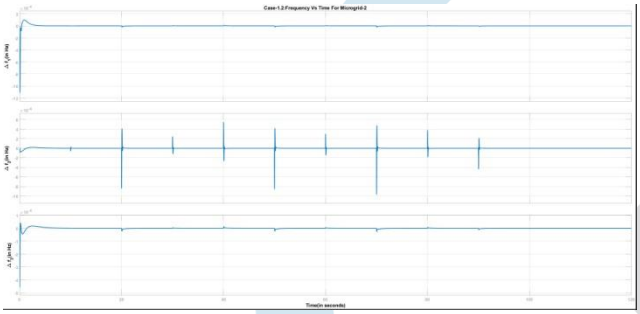
Case 1:Frequency vs Time for Micro Grid 1:



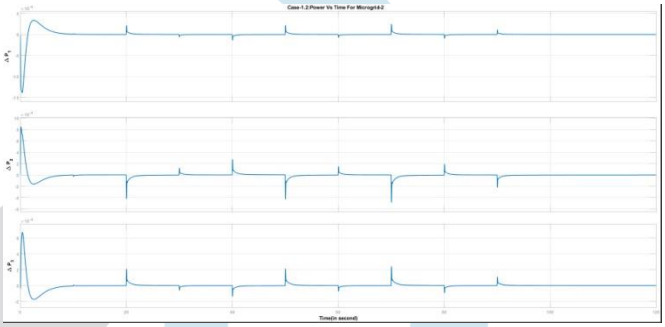
Case 1:Tie-line Power vs Time for Micro Grid 1:



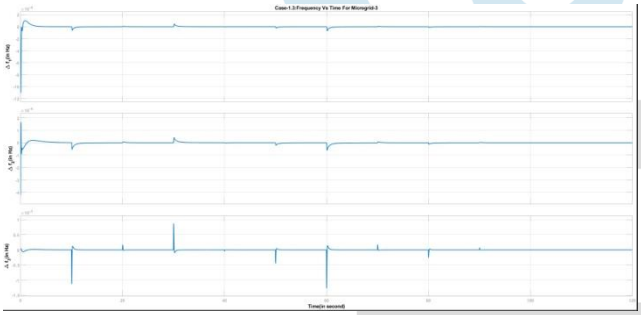
Case 2:Frequency vs Time for Micro Grid 2:



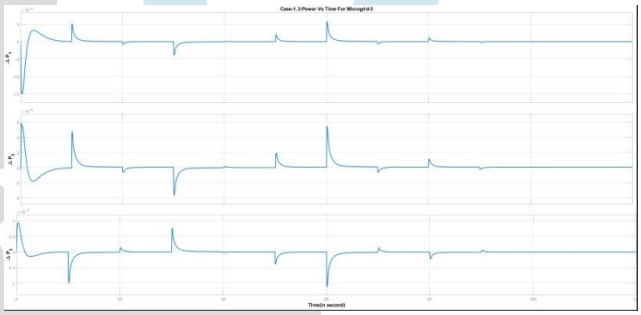
Case 2:Power vs Time for Micro Grid 2:



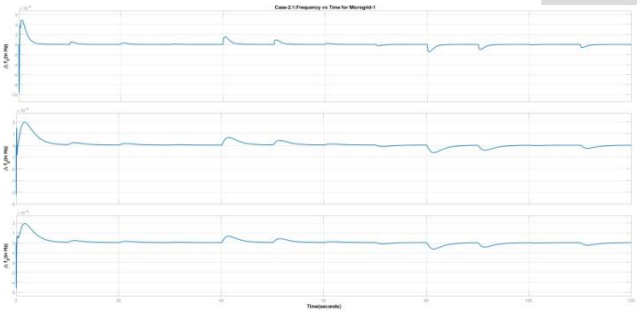
Case 3:Frequency vs Time for Micro Grid 3:



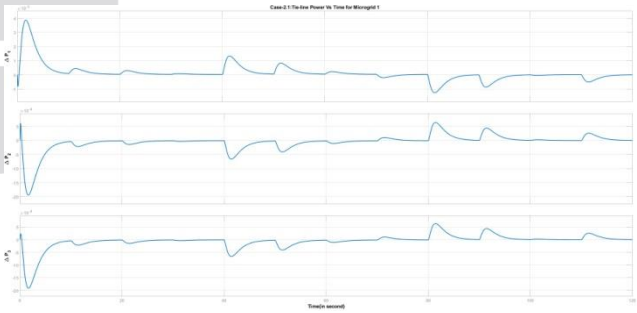
Case 3:Power vs Time for Micro Grid 3:



Case 4:Frequency vs Time for Micro Grid 1:

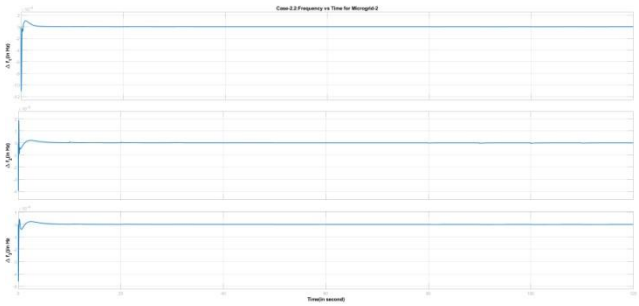


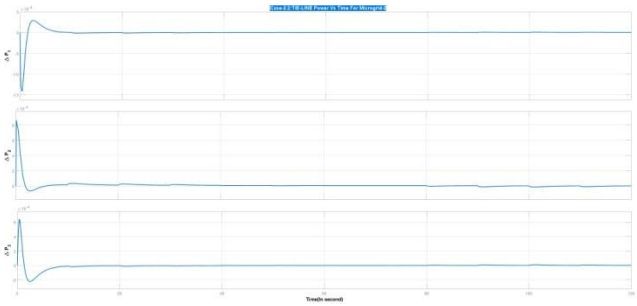
Case 4: Tie-line Power vs Time for Micro Grid 1:



Case 5:Frequency vs Time for Micro Grid 2:

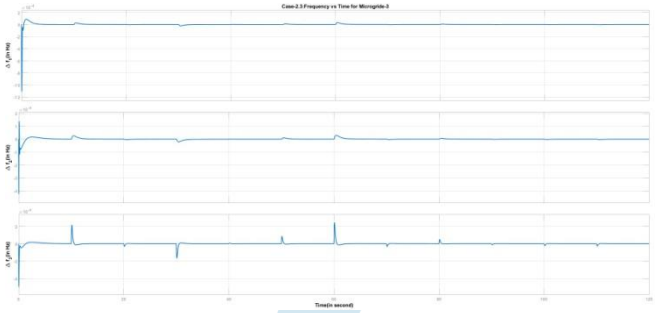
Case 5:Tie-line Power vs Time for Micro Grid 2:

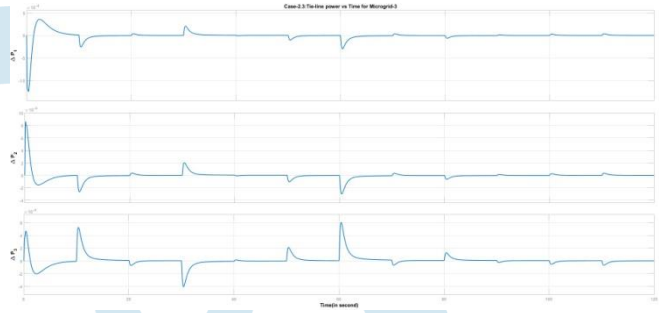




Case 6:Frequency vs Time for Micro Grid 3:

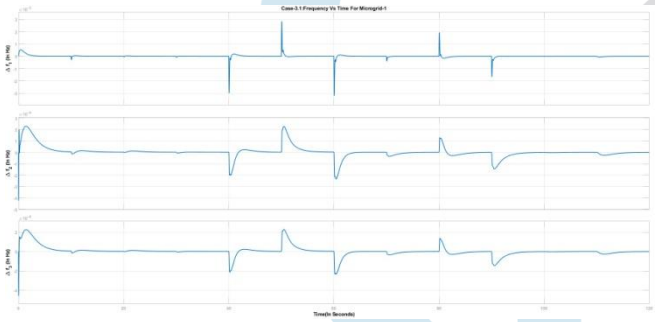
Case 6:Tie-line Power vs Time for Micro Grid 3:

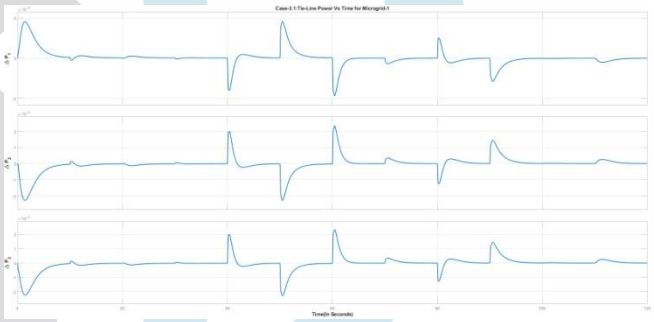




Case 7:Frequnecy vs Time for Micro Grid 1:

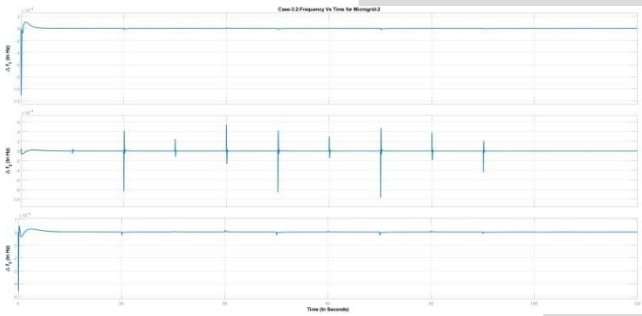
Case 7:Tie-line Power vs Time for Micro Grid 1:

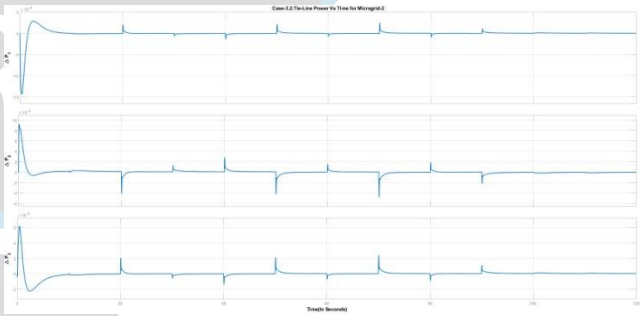




Case 8:Frequency vs Time for Micro Grid 2:

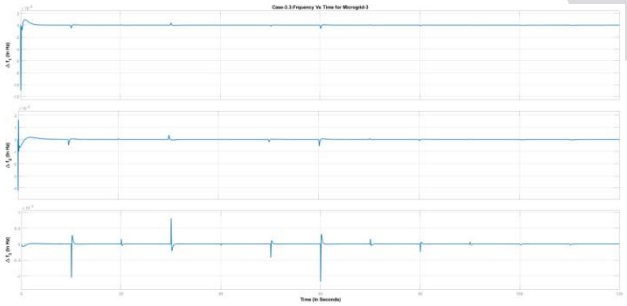
Case 8:Tie-line Power vs Time for Micro Grid 2:

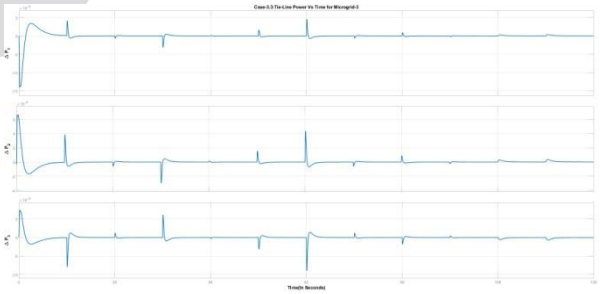




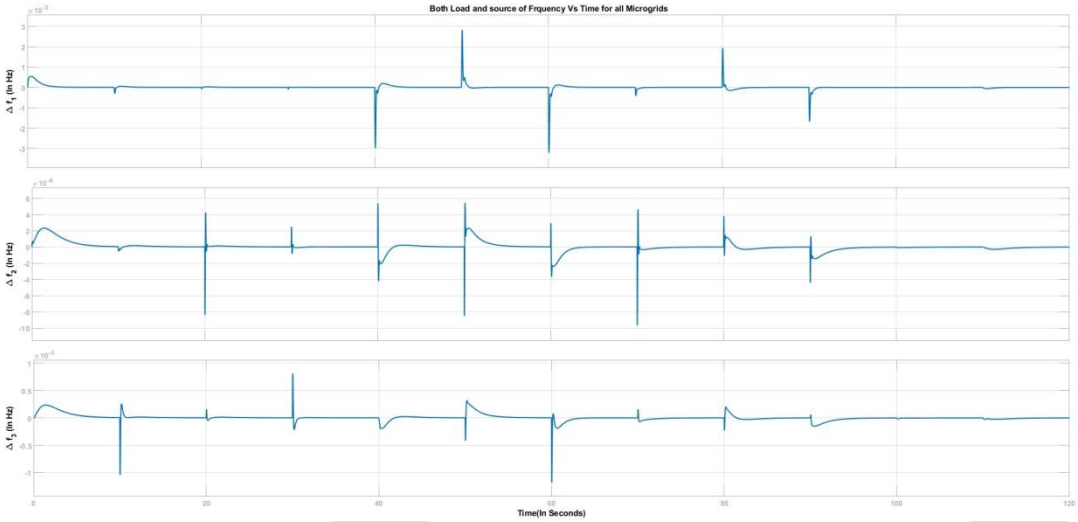
Case 9:Frequency vs Time for Micro Grid 3:

Case 9:Tie-line Power vs Time for Micro Grid 3:

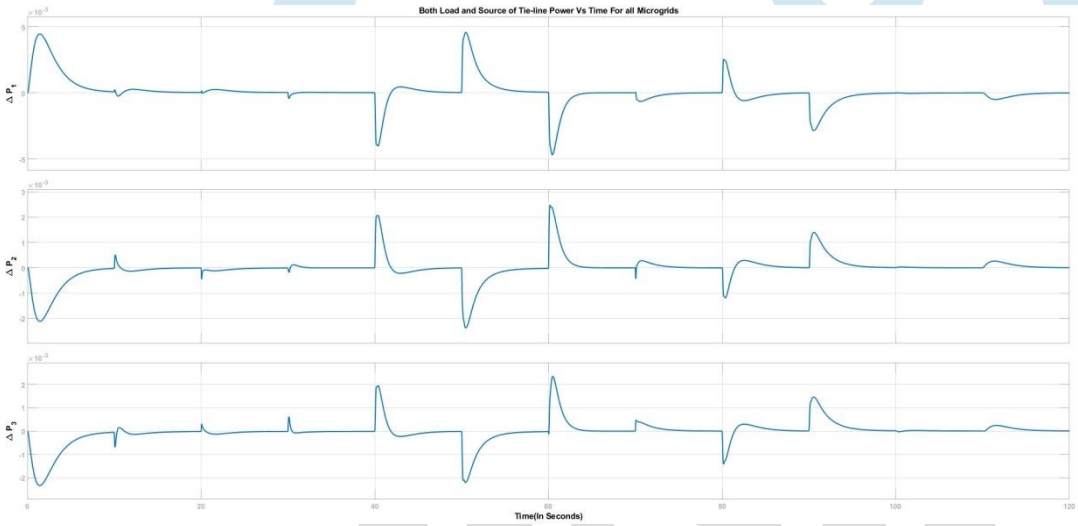




Both load and source of Frequency vs Time for all Micro Grids:

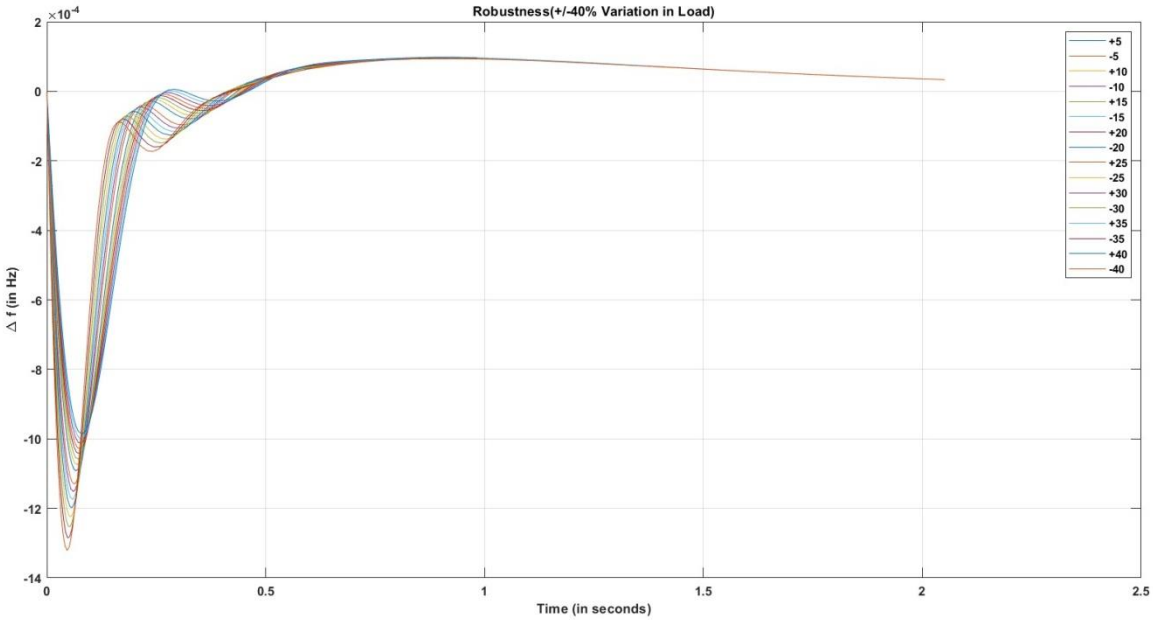


Both load and source of Power vs Tie-line Time for all Micro Grids:



CONCULSION:

It can be concluded that the proposed optimization scheme will always aid in the stabilisation of microgrids with various types of energy and storage units. The controller, in addition to providing stability, reduces the burden on the actuator system due to the smaller magnitude of control signals. Furthermore, the developed system is resistant to changes in load and system parameters. The controller design for increasing the robustness and performance of a microgrid in terms of frequency stability. The FOPID structure is implemented by selecting controller parameters based on the controller's complexity. These parameters of FOPID are chosen carefully by using TlBO algorithm. The microgrid analysed in the work used a combination of renewables such as wind energy, solar energy and Ocean wave energy, as well as energy storage devices such as batteries, Ultracapacitors, Super conducting magnetic energy storage system. Controller performance is evaluated using load and renewable-based scenarios. The robustness of the controllers is tested by varying the microgrid loading in the range of ±40.



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