**NEAR EAST UNIVERSITY**

**Faculty of Engineering**

**Department of Electrical and Electronic Engineering**

**Generator Backup System for a Critical Load**

**EE 402 – Graduation Project Report**

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# Abstract

In unexpected cases, when there is a sudden failure in the power supplied to the facilities specially in the huge ones that require emergency backup systems by diesel standby generators, the installation of emergency backup systems (EBS) is as important as the oxygen we breath, like in hospitals that need to be 24 hours supplying electricity therefore oxygen to patients, electrical systems are being modified, built, and designed in order to ensure maintaining full power supplied to fundamental facilities. they are becoming necessary and critical, the importance of the backup generator followed up with the development of the interior system by performing design and simulation by MATLAB and SIMULINK softwares. Several studies have been done in the field of emergency systems, and this demonstrates its importance in our life. It is necessary to note that the issues of EBS are not new, although all the main issues were considered within this research to make sure we are optimizing the emergency systems on all parameters variations and achieve the most efficiency on such systems, even though, multiple problems was faced during the implementation, but we figured out flexible solutions for these difficult issues, by following certain procedures beginning from the design of the blocks and ending with selecting the appropriate parameters to maintain the best stability and highest possible efficiency throughout the entire system. In our system we managed to simulate a complete emergency system for a critical load by having three diesel backup generators and the main electricity source, the flexibility to switch between them at any point through the simulation process. Basically, one of the characteristics of system reliability has been the power security of the EBS, which states the ability of the system to endure unexpected disturbances without accidental effects on electricity consumers. Simultaneously, the examination of power security was mainly performed on a simulation perspective and programmatical logic. Deeply speaking working this type of projects needed a high accuracy and assuring the perfectly fitting blocks.

# Introduction

Backup Generators are one of the most important inventions in electricity and this is clear from its contribution because it compensates the sudden outage of the electricity especially in important facilities that needs electricity for 24 hours. When the electricity goes out and the facility becomes all down, with nothing working, this would have severe consequences, and you cannot do anything until the assigned service company finds the problem then try to fix the issue and by then the facility will work again, and here comes the importance of Backup power systems.

In electricity generation, the mechanical power is converted to electrical power and through this process, there are many circuits and connections that assure a perfect and successful electricity generation, but there is a critical and essential factor in this process which is safety circuits that guarantee human’s safety and reduce machines loss based on cost, effort and so on, yes electricity is a great invention that changed the whole world in a very great way, it’s a revolutionary invention, on the other hand, we need to be very cautious while dealing with it whether we are just consumers, technicians, or engineers. Hence to reduce risks as much as possible there will come the purpose of this proposal power, safety circuits and connections.

Here we will talk about an integrated system that works when there is a power outage together with the emergency backup system to make sure the power is always supplied to the facility, so this system depends on generating electricity by diesel generators, and the reason diesel generators are chosen is because diesel generators are more efficient in terms of fuel, using only one-third of the amount of fuel as other types, this fuel-efficiency adds up to significant savings over time, longer operating life and lower operating cost compared to other generators, and this system is highly reliable as well as high efficiency.

Our job in this project is to simulate this system on MATLAB and SIMULINK softwares and estimate the most real situations and guarantee the most accurate execution in the real life, going from the absolute beginning of studying the whole system and analyzing every and each part precisely in order to have a clear vision of what we want to achieve at the end, working in such system was very highly structured and organized, we took it step by step, block by block till we move to a new phase after ensuring we achieved the best result in that particular phase.

## Aims and Goals

The main goal in this project is to design and simulate a generator backup system for a critical load with selecting certain parameters for the applied sources and following a particular implementation for the whole system. At the same time, we have combined and make corresponding of the generators and the critical load powers in order to make a match for the measurements of the other blocks to be synchronized. We also made sure to provide the blocks that ensure the full safety for the circuits in order to be compatible with any failure the system could have; also, we provided a certain sequence for the generators to have a cooling period. Last thing was designing the control panel application for having the opportunity to control the simulation process through it.

The complementary goal for this project was gaining the experience of team work; it was new trial for most of the team members but it was necessary for engineers to know all the different aspects related to co-operative work and gave us wide knowledge to share between us.

We had the opportunity to make the simulation test multiple times and that generally led us to know and learn more about the specification of every block we used in the program by following the modification procedure throughout the whole system and especially matching the parameters that were not given in the description.

The goal was reached by dividing this work among us, we consist of six members in the group and each of us worked on his own task as follows:

* First task: The design and simulation of Diesel engine powered generators.
* Second task: The design and simulation of load balancing and synchronization of generators.
* Third task: The design and simulation of all the power and safety circuits and connections.
* Fourth task: The design and simulation of generators and mains failure and become operational events during the course of system simulation.
* Fifth task: The design and simulation of remote monitoring and control of generators via internet link.
* Sixth task: The design and simulation of intermittent operation of generators. Such as, each generator shall go to a cool-off period in turns after 8 hours of operation. Once a generator comes off from its cool-off period one of the other generators shall go to a cool-off period.

## Difficulties

Difficulties are considered challenges to accomplish any task, so we must challenge the circumstances and difficulties where the graduation project is one of the most important stages that any student goes through in the university and therefore there must be some challenges and difficulties at this stage of university life therefore it required us to face such difficulties and to find solutions, such difficulties that we faced as a group doing this task and how to complete the project to avoid any difficulties and there are many difficulties faced by the student and set a plan to face such difficulties I want to talk here about some of these difficulties:

In the period of **COVID-19** we faced many difficulties individually and in terms of the team too, in the following points I will show the difficulties that have been faced during the timeline of the project.

* Research: In our university life we learned to work as a team when we face any difficulty for this although we do not have full knowledge in the management of the graduation project and how to work continuous research in many books and references that concern our project about the electrical monopoly system and the work of the simulation system for this project and works without any problems at work.
* Meetings: Also, of these difficulties, which are the most important ones, which is meeting and working as a group and was exceedingly difficult in the presence of the virus Corona spread in the world that we were stopped from meeting with each other and traveling to Turkish Cyprus to meet and accomplish tasks and we had to meet via the internet on one of the applications and complete the project with high accuracy.
* Program selection: Difficulty chose the program as the lack of knowledge in the programs that specialize in the work of simulation where it was one of the difficulties and require us as a team to overcome this difficulty and work a lot of research to choose a program that does this job.

## Contribution

Let us start directly by giving a brief explanation of the definition Backup power generating system and its importance in our daily lives, one of the main purposes of that system is to improve the reliability of the power used. That system is restoring so quickly and maintaining the parts of the facilities, campus, territories powered up for minutes, hours, or even days. If the utility power has failed to do its main function for a few seconds, the backup system is operated to reduce the costs of the utility power in some particular cases, the interruptions of the electricity can happen anywhere, anytime and can last for seconds or even hours without a previous warning. This is dreadful thing for food companies, government institutions, hospitals. Because in food companies an entire supply can be thrown out for manufacturing factories, in hospitals we are talking about life and death, for the working companies round the clock the power is so critical and decisive factor. many commercial and public companies are always purchasing the backup power units in order to avoid the losing in time and also losing the contact with customers due to electrical disruptions, if the employees can get back to work as soon as possible and go on with operations, the minimum the hit will be to the bottom line during the power outage. The backup power system also can protect business facilities from theft, and I will explain why, if a power failure happened and extended for a long time, your premises might be exposed to looting and break-ins. The backup system helps and enables you to protect your business from potential intrusions by the feedback of restoring security system and lighting instantaneously. It also can protect your business from weather, as we all know the extreme weather can cause disruptions as well as humidity, freezing and high temperature conditions. It also protects you from hacking, these days the threats from hacking of cybersecurity due to terrorism are so rapidly increasing, so the backup system can ensure you can fight back these threats in case of power fail, also one of its most important advantages is the ability to hedge, to able to transfer a backup power system unlock your business to the option of alternative energy plans that can save you money, let’s take an example, you can find a demand response program that helps you lower the bills as the same as generating income by paying you to minimize or shift the usage of electricity during the peak time. The backup power system can be in different sizes and shapes, with the most popular being natural gas fired or diesel generator that has been installed on site, the facilities of cleaner energy such as biogas, solar panels or wind turbines can also constitute or compose part of the backup energy solution. but the most common thing between all of them is the ability to supply business resilience by ensuring the access of the electricity all the time. One of the most important sectors that desperately needs that kind of a system is the education sector. Colleges, schools, higher learning institutions, all of them have huge educational systems powered by electricity and unfortunately if power failure happens that can lead to great inconveniences, most of the systems include phone networks, lighting, research equipment, fire alarms, ventilation, elevators, data storage, computer networks, cooling and heating. All of them play an integral part to guarantee the comfort and relief of the students as well as the functionality of the educational system, without that important system the school may be obliged to shut down some time of the day due to interruption in the planned studies. That can put the safety of the students in danger and require the school to negotiate with the parents to pick the children early out of the school which can be a real nightmare because of emergency and safety and most of those parents will not be available due to their jobs, for the higher learning institutions the power failure could result in money and time losses for the faculty and students. Most of the important and integral data could be vanish and there will be damages with the vital equipment, it will also be impossible to proceed experiments of time based and power during the outage or even after the restoration of the power.



Figure ‎1.1: Diesel Backup Generator

As we previously mentioned in case of any failure in the power from the main source, any buildings that depend on the backup power system for both safety and the public health as well as the protection of business facilities which will be an awful disaster if it is suddenly lost due to a power outage. Unexpected crisis usually disrupts the power to hundreds of thousands of businesses and people. Many facilities such as airports, hospitals, data centers, gas stations, water and sewage facilities, transportation and telecommunication systems that need some kind of replacement power to eventually save lives during the case of disasters. The power disrupt to a business facility can cause a substantial economic impact, the longer the business in the most need of power, the greater the economic losses, when these unexpected dystopian occur, the backup power system provides a source in order to support the loads of the equipment through uninterruptible power supplies, generators or even battery storage system.



Figure ‎1.2: Battery Backup Power

## TIMELINE

Figure ‎1.3: The Gantt Chart

This figure (1.3) shows the timeline of the project from 6th April when building the team till presenting the project at January 2021 and it shows the duration of each task based on the estimated length of its rectangular bars. the project will be prepared during 2020 summer like working on the design and simulation till writing the report then presenting the project at January 2021.

The timeline shows all the milestones that we went through from day one in the project till we finally worked everything out and get the system to fully working state based on all the design criteria that was specified to us.

## BUDGET

The table below shows the budget for the whole project. The table clearly states the name of the software we used and a brief description of the specific type of the item.

Table ‎1‑1: Table for Budget

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No | Item | Type | Description | Total cost |
| 1 | Computer Software | MATLAB and SIMULINK | Design, simulation, and programming | 55.5$ |

The Table 1.1 above explains the softwares we need to complete our simulation with the type and description of the item that we need to work on, as well as the price of one item and the total price given in the US Dollar.

As you can see, we are going to need only a computer program for this task in order to make the simulation closer to reality as possible.

# Literature Review and theories used

In this section we will be talking about the history of Backup Generators, when it has been used the first time, how it was working, then we will advance with the topic through the evolution of the electricity and its effects on the evolution of Backup Generators.

We are going to provide the process that we went throughout this project and we are going to talk about the simulation procedure that was done in addition to all the steps of the design and combining the components in a practical way, also we will be giving the full explanation of the cases that could happen according to our tasks.

We chose MATLAB Simulink program to make our work done due to its ability of making the imagination closer to reality. You will also find the theoretical principles and foundations of how the system of Backup Generator systems work in a simulation perspective.

## LITERATURE REVIEW

Developers and engineers have proven that the electrical backup generators to be one of the most fundamental devices that most of the people use among different facilities, the dependency on device that can generate electrical power instead of the main electricity source can ensure safety, saving lives, and saving companies from collapsing. Even though, we see that most of the backup generators are founded in important facilities only, but developers expects to have generators among other vital facilities in order to ensure the full security around several business and establishments. Talking about the importance of the electrical, medical facilities are one of the most essential complexes that need power supply to be generated continuously, so what if the main source suddenly failed to supply the needed power? It could lead to various losses. So we can say that critical establishments such as industries, companies, and private complexes in general need a backup system to generate the electricity among them.

The first stage of the invention goes back to 19th century, the first discovery was the electromagnetic induction event which the same of that what we call today “Faraday’s Law” which is basically a generation of an electromotive force inside an electrical conductor.

The first development came in 1932 by building the first dynamo generator.

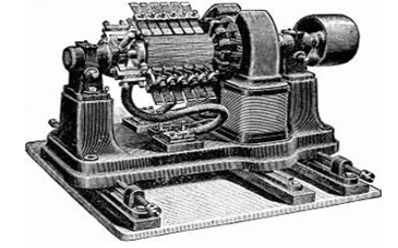


Figure ‎2.1: Dynamo Generator

The figure 2.1 is the first design of a dynamo generator; this development was invented to deliver power by the pulses of electricity and without a current passing through.

The invention of the generators is already considered as main purpose for humanity at the 19th century, but also the development of these devices is important, as the development grows, it became easier for usage and more safety is ensured to try as much as possible to cover all the possible situations damages that could happen.

The first electrical generator was the dynamo generator, this model was invented without current but with pulses of electricity and it was first electrical generator to deliver power for industries. After that, the development was focused on the elimination of the alternative current to reach the direct current power.

The next developments of the dynamo generator focused on providing continuous DC power and creating self-powered electromagnet rather than the weak permanent magnet, and this development was successful in different aspects either from its power or usage in general, this operation remained until it went to the discovery of the AC systems. [1]

Until now, after many researches and studies, we reached into the generators that make an implementation by substituting the power supply into the electricity by running water turbine; this process provided larger energy that it is more than enough. These generators are usually different in size, they are usually larger. At the same time, the well-known generators that are founded in the commercial and residential facilities, these types’ works by fuel sources such as diesel, propane, and gas. [3]

Generators that depend on their sources from fuel were the latest development reached in the past years, and diesel generators left a great impact mostly among their other competitors due to their ability to supply power to the load directly and also the ability of storing the generated power in their batteries. They are mostly used and founded in modern industries. [3]

The greatest development reached for generators is highly contributed with technology and especially the smart devices, now we have the ability to control the generators from mobile applications and from internet links as well.

As we know, the main purpose of the generators is to supply power in case the main power supply failed for any reason, but there also other reason of the generators in other aspects, some work totally depends on them in different ways, so here are some examples of the generator usage:

Backup power for business facilities: The best way to ensure uninterrupted power supply in the medical facilities is to put extra resources that can supply the same process. Hospitals are required and responsible to maintain the full power all over the departments for the patients in order to ensure the safety of their patients. [4]

Construction areas: The construction working points require many different electrical devices to be working such as: machines, trailers, ventilation, saws, grinders, drills, and other tools, and usually construction areas contain main power source but it often cutes between a time and another unexpectedly, so it is necessary to have a backup power supply in such cases. [4]

Agriculture and ranching facilities: The usage of the generators in agriculture facility is sometimes considered as primary sources to supply electricity for water pumps. The irrigation systems usually work from the generators power supply. [4]

Mines: mines facility also uses the generators widely to get their work done; the estimation of the mining operation from generators is about 70%, their need for it usually concentrated in shovels, excavators, and lightning up the deep tunnels for the workers. [4]

The usage of the backup systems is not confined around working facilities, but also generators are used a lot around other activities such as: weddings, fairs, sporting events, and camping. [4]

The future of generators and their systems in general is very wide due to its improvements, efficiency, and simplicity of work; developers expect to have generators capable to be friendly with the environment and reduction of its loud noise as well as the discharge of the chemical gases, and the future generators is associated with the requirements of the people needs especially in critical facilities. In financial aspect, diesel generators sales are expected to be growing up to 21 billion dollars in 2022 which means a huge range from the market in 2014 which was 12.6 billion dollars. Energy information administration is expecting that the developing countries will represent 65% of power usage in 2040. The contribution of the simulation with generators in the future is also high, because the expectation for this process method is associated with the climate scenarios. [8]

## THEORIES USED

In this section we will talk about the components used in the project with design and simulation perspective, the circuit, or the Blocks that we used in the simulation and the connections that made the project.

The connection, the blocks will be demonstrated in detail as also their parameters.

This will be divided into the following parts:

* A block Diagram for the basic structure of the backup system.
* Sections of the system
* The main source of electricity which is called the grid.
* The safety circuit components used in diesel Backup generators and the whole system.
* Connections of Components or blocks.
* Table of Cases for the operation cycle between the backup generators and the grid

Before going deeper to all the theory we used in the project we need to talk about all the components in a simple and detailed way, the components will be explained from circuits in real life then estimate them with components used in Simulink that functions similar to it.

### Three-Phase SOURCE

The main source section in our system was designed in Simulink by 3 blocks, which are the

* Three Phase Source
* Three Phase Transformer
* Three Phase Breaker

**Three Phase Source**

In a symmetric power supply framework with three-phase, each one of the conductors can deliver voltage magnitudes and alternating current with a similar frequency relative to a typical reference though with a phase difference of 33 percent of a cycle between each phase. The basic reference is typically connected with the ground and it is regularly connected to a current delivering conductor called the unbiased. due to the stage dissimilarity, the percentage reached by the voltage on any conductor reaches to the maximum cycle at 33 percent after one of the other conductors and reaches 33 percent of a cycle before the leftover conductor. This phase variance gives a stable power to move to a fair straight weight. It additionally makes it feasible to create a turning attractive field in an electric engine and produce other stage courses of action utilizing transformers (for example, a two stage framework utilizing a Scott-T transformer). The sufficiency of the voltage contrast between two stages is times the adequacy of the voltage of the individual stages.

The main role of the block of three-phase source is distributing three-phase voltage along with R-L impedance internally. This block is usually connected as wye-connection (Y) and can be available when it is either connected to the ground or to a neutral connection. There are two ways to make a specification of the internal source and they are named as direct and indirect specification, either by putting the values of R and L or by and this is the direct way, or by appointing to short-circuit level induction and the X/R ratio and this is the indirect way.

A picture containing engine, vending machine

Description automatically generated

Figure ‎2.2: Three Phase Source

**Block Parameters**

The parameters values specifically should be selected carefully in order to ensure the result of the desired system, as the connection internally is wye-connection (Y) alongside the ground which symbolized as Yg in the system.

All the values are already set in figure 2.3 above, the voltage is 13800 V phase-to-phases, the angle is 0.071468°, and the frequency is 60 Hz.

The induction of the three-phase short-circuit power is given with SI unit of volt-amperes (VA); it indicates the internal inductance L. The default value is 100 KVA. The availability of the parameter is contributed with the selection of the internal the parameters of short-circuit level.

The calculation of the internal inductance L is founded by the equation given below, its value is in Henry (H), and the value is calculated from the power of the induction of three-phase short circuit (Psc) with VA as SI unit, Vbase and it is phase-to-phase voltage with volt rms value, and the frequency in (Hz).

Equation ‎2‑1

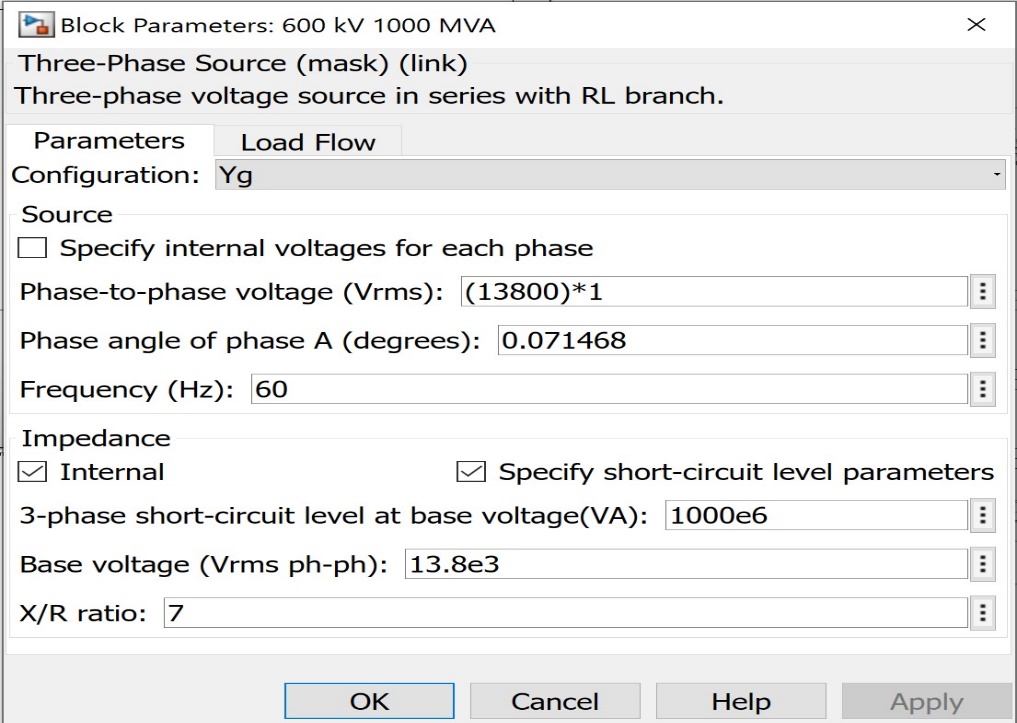


Figure ‎2.3:Three Phase Source Parameters

### Three-Phase Transformer

In this part will show some theoretical view over the component then we will talk about the component in specific with parameters and configuration and then more practically in the work done chapter.

**Types of Transformer**

There are different types of transformer in the electricity and used in the electrical power systems for several purposes, like transmission, distribution, generation, and utilization of electrical power.

The diverse types of transformers are classified as Step-down and Step-up Transformer, and they can be for the current and the voltage transformers, also there is Instrument transformer, Power Transformer used in electricity generation stations, Distribution Transformer in population areas to distribute to houses or buildings, comprising current and Potential Transformer, Auto Transformer Single Phase and Three Phase transformer.

**Three-Phase Transformer Block.**

This block implements a three-phase transformer using three single-phase transformers.

When activated, the saturation characteristic is the same as the one described for the Saturable Transformer block. If the fluxes are not specified, the initial values are automatically adjusted so that the simulation starts in steady state.

The leakage inductance and resistance of each winding are given in (pu) based on the transformer nominal power Pn and on the nominal voltage of the winding (V1 or V2). For a description of per units, refer to the Linear Transformer and to the Saturable Transformer.

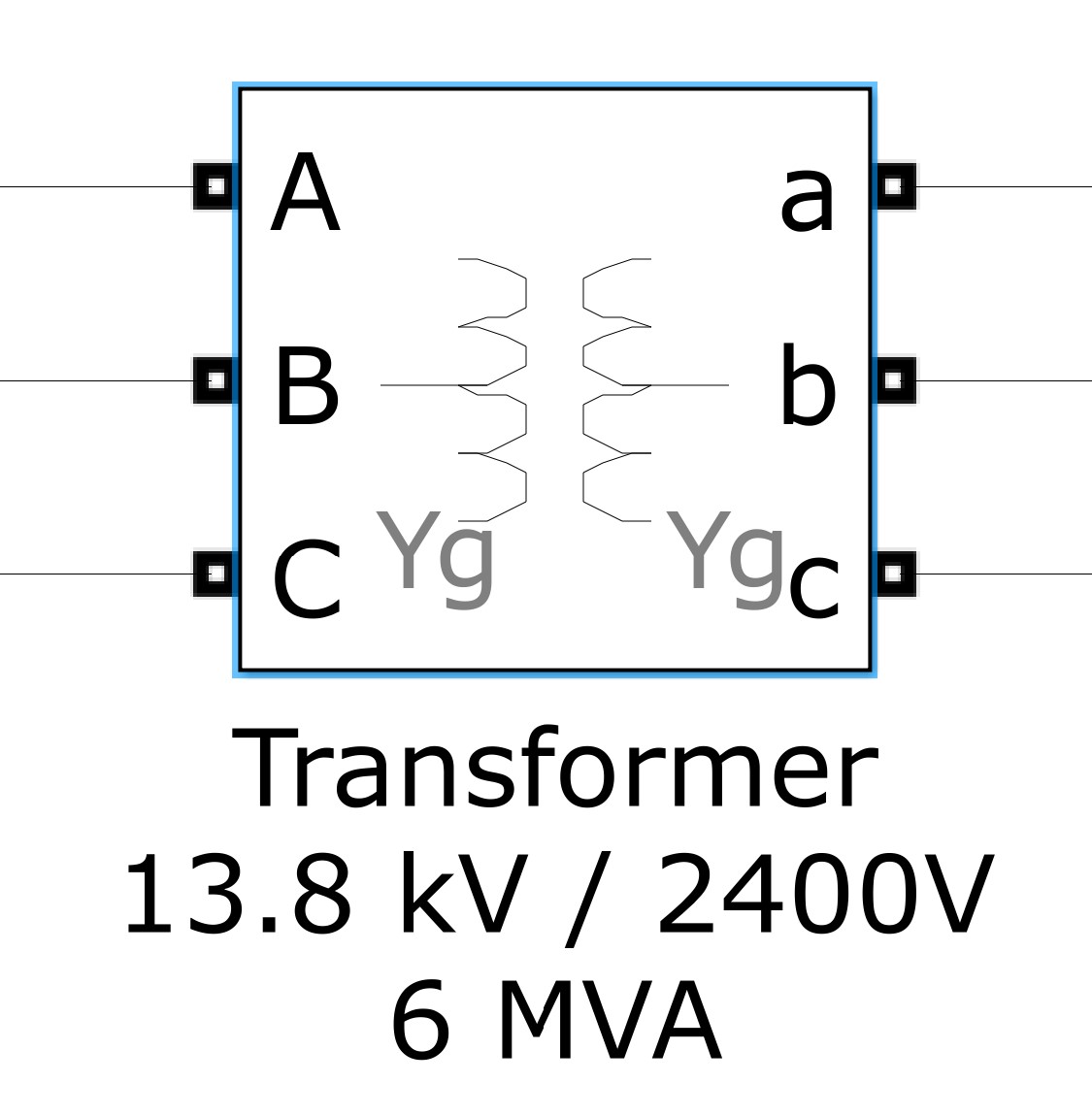
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Figure ‎2.4: Transformer

**Block Parameters**

The primary Connections are connected in Y connection to the ground as indicated by Yg

As well as the secondary connection. The core type in the transformer is three single-phase transformers.

The nominal Power Pn is set to 5 MVA, and the frequency is set to 60 Hz.

The Primary windings parameters are set to 13.8 KV as Ph-Ph and R1 is set to 0.0015, and R2 is set to 0.03.

The Secondary windings parameters are set to 2.4 KV as Ph-Ph and R1 is set to 0.0015, and R2 is set to 0.03.

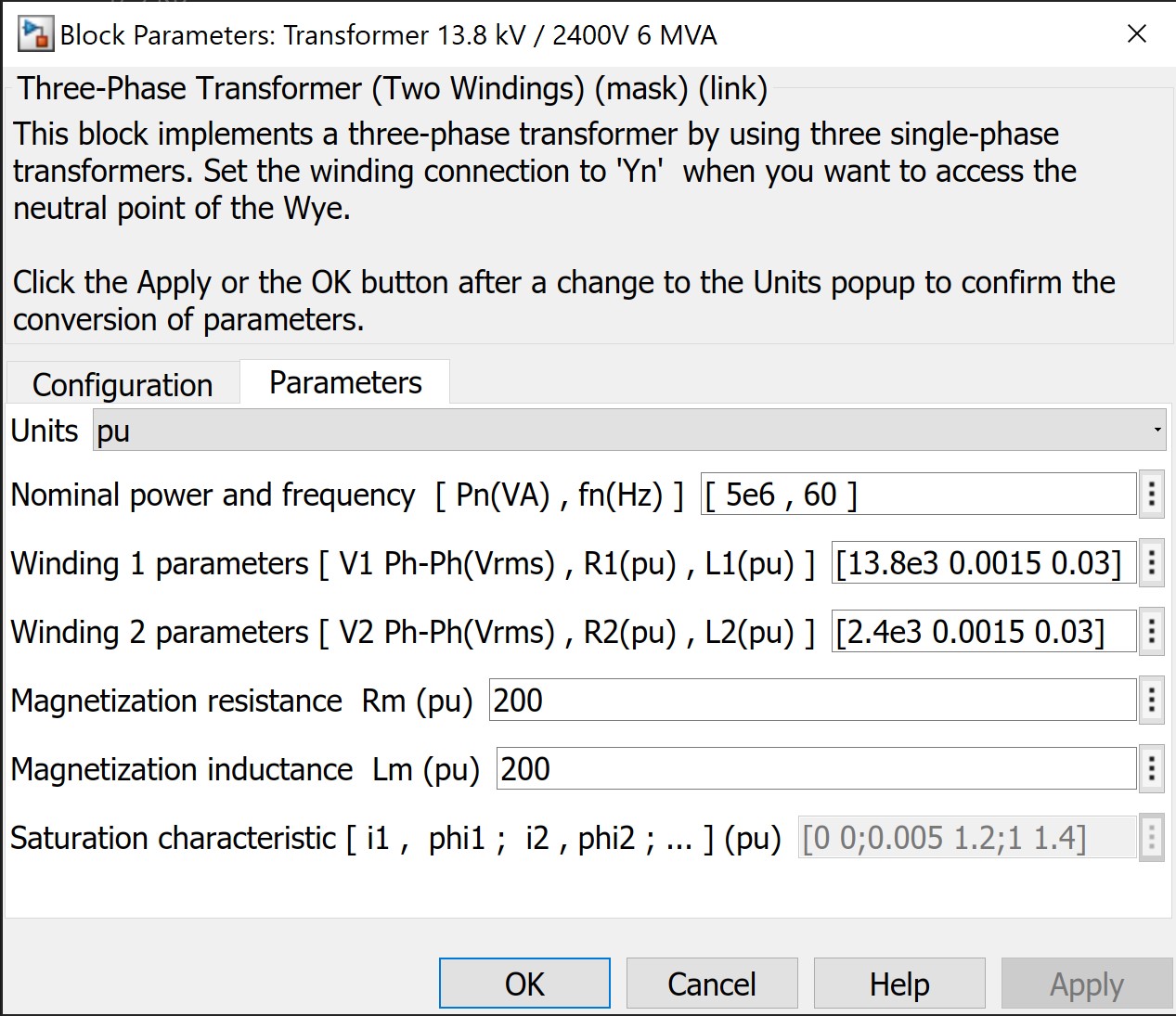
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Figure ‎2.5: Transformer Parameters

### Three Phase Breaker

The circuit breaker is in the main source section is one of the most important components in our system, it is the key part of switching of and on the grid when there is any failure in the system.

We represented the failure in the system by a controlled constant with values zero and one.

The circuit breaker is essential in the safety of our system, it is common activated type, in other words when the circuit breaker receives zero it opens the circuit and there is no current flowing to the load, at the same time there is opposite signal flowing the backup system to ignite it to work.



Figure ‎2.6: SF6 Circuit Breaker

A circuit breaker is and electrical device that can operate automatically this electrical switch is designed to protect any electrical circuit from and unexpected damages than might be caused by an increase in the current by a short circuit or from an overload. It is main function is to intersect the current flowing after any fault happened in the entire circuit.

Opposite to the fuse, which only works directly by replacement, this means that the circuit breaker can enter the reset mode in order to complete the action in a stable way. The reset mode can be given as orders either manually or automatically

The sizes of the circuit breaker vary between a type and another, some of them are small devices and some are consisted of large switchgears, the variation among them also comes with difference of functions. To get the protection to the circuits contributed to either the low-current protection or appliance of the household of the circuits, this is the small devices role in general. By removing the power associated with the wrong system, we ensure the functioning process of the fuse or circuit breaker.

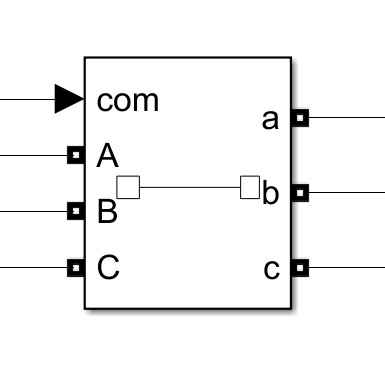


Figure ‎2.7: Circuit Breaker

**Block Parameters**

The initial status of the circuit breaker is set to closed as we want it to open when it receives a signal with value zero, breaker resistance is set to 0.01 ohm.

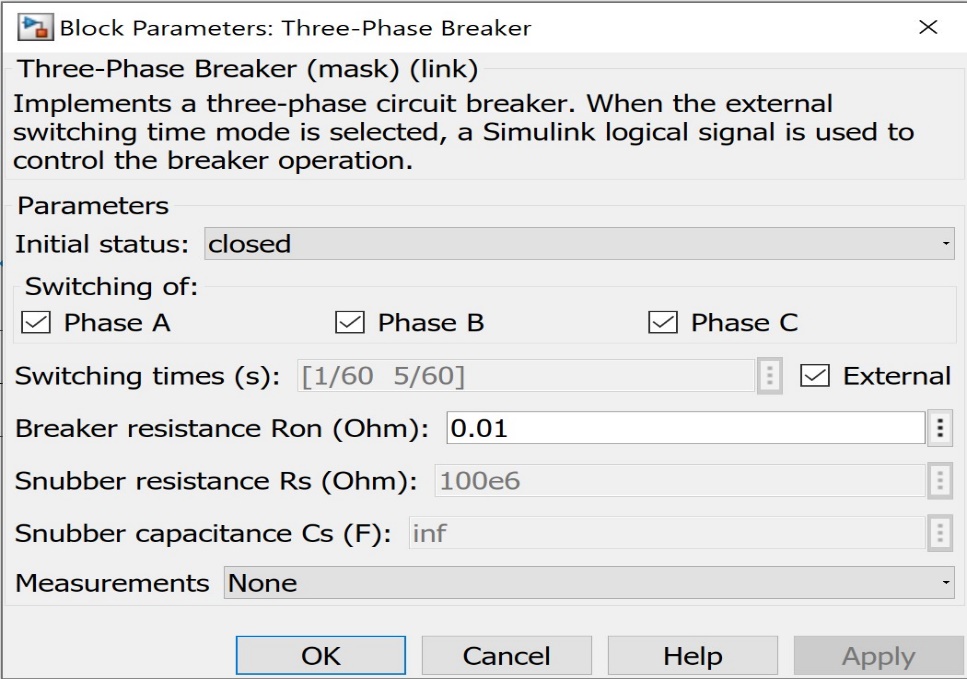


Figure ‎2.8: Circuit Breaker Parameters

### Automatic Transfer Switch (ATS)

This is switch is one of the key-element in any emergency system because its benefit of self-acting depending on whether there is a failure in the system or not, so if the grid fails for any reason it activates the common input in the circuit breaker therefor the breaker breaks the circuit, and the backup generators get to work.

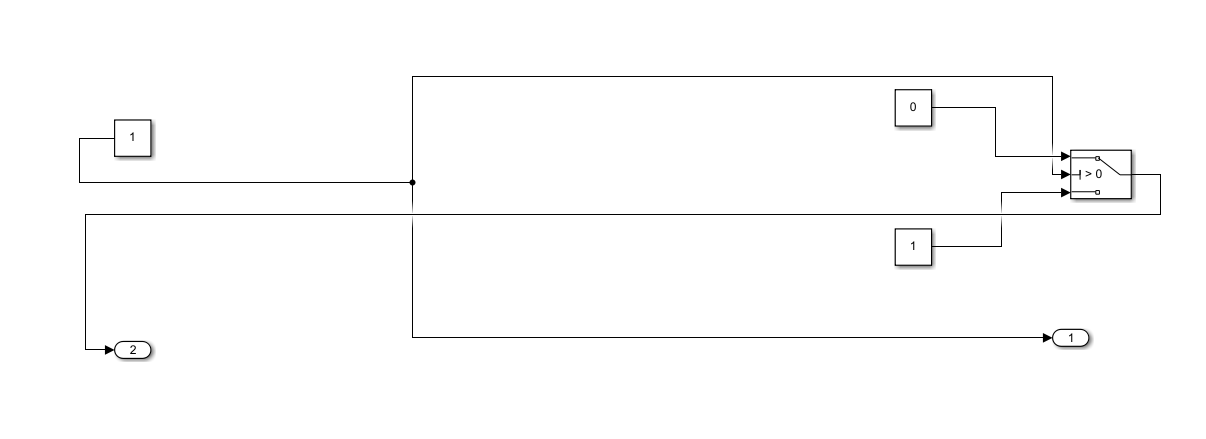


Figure ‎2.9: ATS Circuit

The functionality of the ATS shown in the figure above is as following, the port number one and two are output ports.

The constant about the output port 2 is what controls the ATS function as this constant is switchable through a Rocker Switch and by this way, we are simulating the failure of the system, by switching it off or on at any moment we want.

So that controlled Constant if its value is 1 it compares with the controlling input in the switch.

If 1 > 0 the first input in the top will flow to the output port number 2, if 0 > 0 which is not correct then the last input at the bottom will flow to the output port number 2.

If the output port number 2 has the value 1 then that means the output port number 1 has the value zero, hence the main source will be off since it is depending on the output port number 1 because it is connected to the circuit breaker.

Therefor the backup generators will operate because it is receiving the value one.

### The Cooling System

One of the most challenging milestones in the project was the cooling system, its idea is to get the most efficiency from the whole system, by making sure all the generators are working on different periods of time, each generator shall go to a cool-off period in turns after 8 hours of operation. Once a generator comes off from its cool-off period one of the other generators shall go to a cool-off period.

This means there will be only two generators are working at the same time and one is in rest mode, and this means 2 generators will work for 16 hours continuously within all the 24 hours and one generator will be switched of for 8 hours between its operation time in the 24 hours.

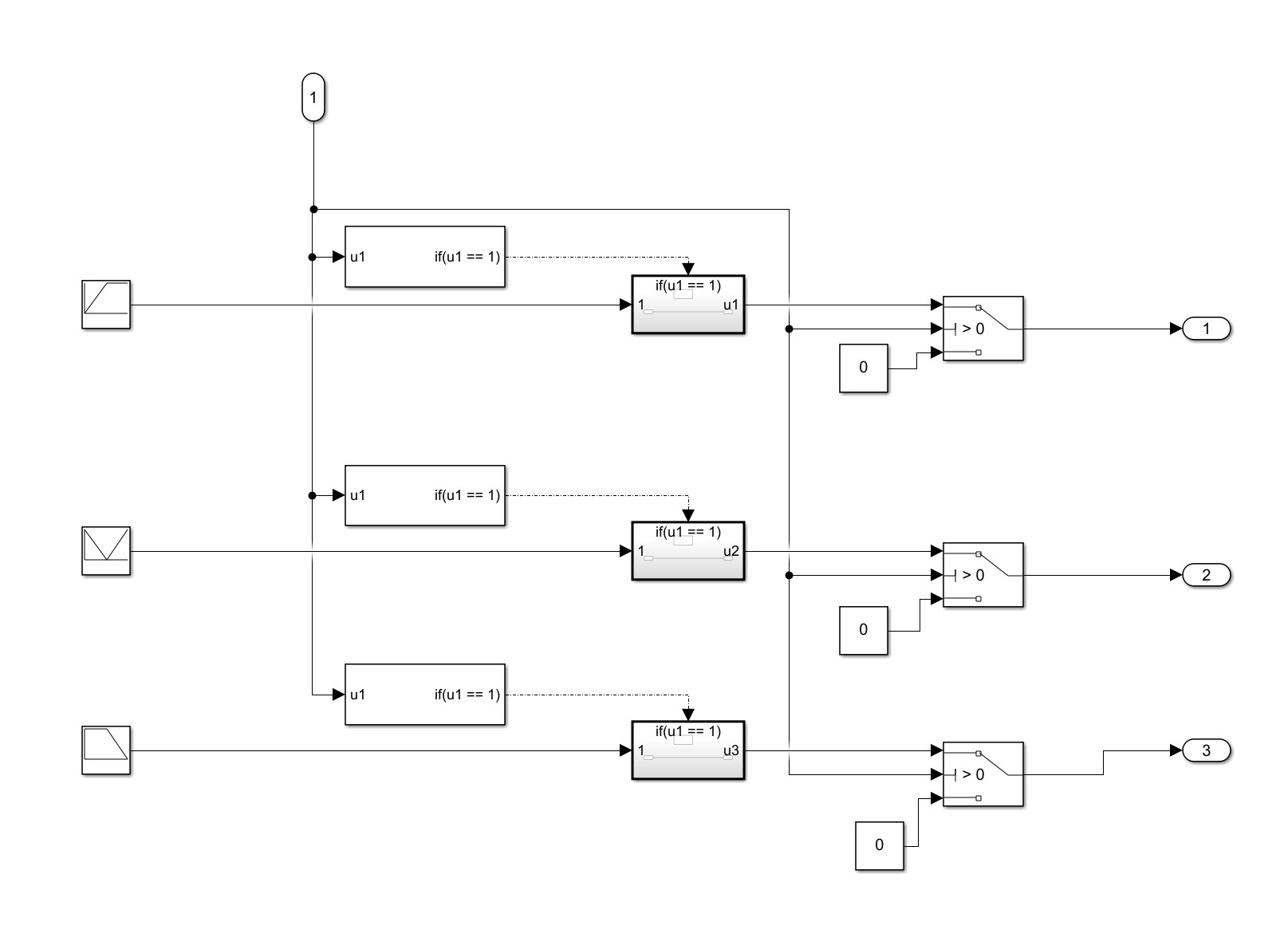


Figure ‎2.10: Cooling Subsystem Connected to Generators

The components used in the cooling subsystem are listed in the next lines.

1. Three Repeating Sequence Blocks.
2. Three if blocks.
3. Three if action subsystems.
4. Three Switches
5. Three constants with value zero

**Repeating Sequence Blocks**

These blocks outputs periodic sequences based on the values being set in vector of time values parameter and vector of output values.

**IF Blocks**

The if blocks are ensuring the ATS function throughout the cooling system if the input is set to 1 then the if function will make the sequence block flows to the generators.

**IF action subsystem**

Each if block must be connected to if action subsystem to apply the logic.

**The switches and their constants**

Are to make sure if one and only one is coming from the ATS then the generators shall work if any other value than one is coming the value zero of the constant will be directed to the generators.

**Cooling Periods**

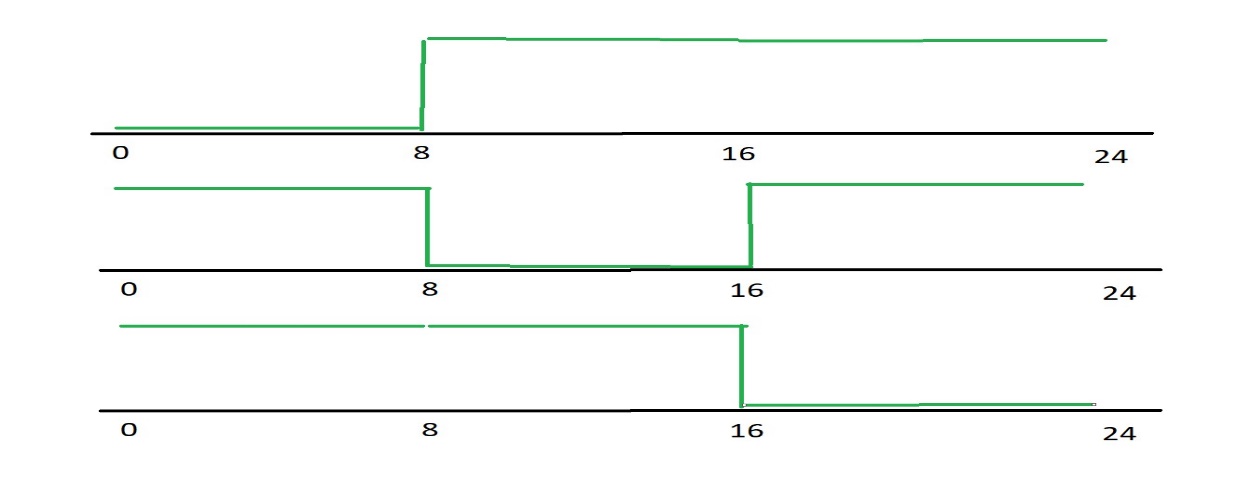
****

Figure ‎2.11:Clocking period

The cooling periods and their switching times are shown in the above figure 2.11, as shown each generator will work at least 8 hours, and maximum 16 hours to guarantee the system is being efficient and gets enough rest.

The repeating sequence blocks are the ones doing these procedures, they are depending on the following logic.

Table ‎2‑1: Cooling Function

|  |  |  |  |
| --- | --- | --- | --- |
| Generator 1 | Generator 2 | Generator3 | Function |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 1 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 0 |

**Cooling Function**

Equation ‎2‑2: Cooling Function

As the cooling function logic shows, there will be always two generators working at the same time and one in rest mode.

The output column is showing when the system will always have two generators on and when the system is not working at all.

### The critical load of the system

The load connected to the entire system is 500 KW, and it is supplied by power from the grid as the primary source and the generators as the secondary source, in case the grid failed to supply the needed power. It makes the implementation of the RLC load as three-phase. The main connection is between the generators and the main source, where the circuit breaker is connection among them. The connection of the load is three-phase connection.

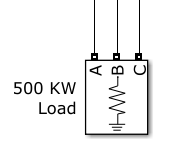


Figure ‎2.11: Critical load

The implementation done by the three-phase load block is RLC series connection in order to have balanced power supply, the connection made is series with the RLC combination elements. The load makes the impedance constant at certain frequency. The power supplied to the active and reactive powers by the load are compatible with the square of the applied voltage.

**Block parameters**

The parameters values inside the load are set to be as seen in the figure 2.12 below.

The load was designed based on the design criteria of our system, as the load is set to 500 KW.

It is configured to have Y connection with ground and the nominal phase to phase voltage is 2400V

The nominal frequency is set to 60 Hz.

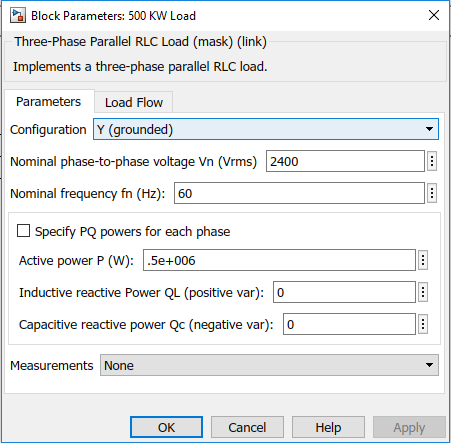


Figure ‎2.12: load parameters

### The generators

The design procedure of the three generators contains same characteristics in general, they are all made at the same exact parameters values, same fuel system, and with same connections as inputs and outputs so we can have synchronizing and balancing between them and the load. The generators subsystems blocks are made with combinations of multiple block so we reduce the size of the design and the ability to have more work space for the other designs of the complementary blocks.

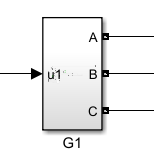


Figure ‎2.13: The generators circuit design

The components compiled inside the generators are:

1. Synchronous Machine
2. Excitation
3. Diesel Engine Governor
4. General expression
5. Switch

**Synchronous Machine**

The block of synchronous machine is considered as the responsible block for interpreting the movements of the current and voltage; it acts the control unit among the connections done in the input by giving the supplying power operation done as output. The mechanical power states the sign mode for the generator as positive and negative for the motor, and the whole operation is made after this detection. The representation of the electrical part is made by a model of 6th order state-space.

The dynamics of the field, stator, and damper windings is considered by the model. The representation of the model’s equivalent circuit is done in the reference of the rotor frame. The parameters of the rotor and electrical quantities are seen from the stator. Their variables are primed specifically.

The theory compiled with the synchronous machine states that the reciprocal inductances among the armature, damper, and windings directed are the same. This gives us the result of having an extra inductance that concludes the equivalent circuit of the dynamic model.

We were allowed to make specification for the fundamental parameter of the synchronous machine as well as the parameters of the resistances, leakage inductances, and mutual inductances in per unit values. By this procedure, the computation of the base values of windings.

The magnetization process of the inductance is made due to the activation and opening of the stator windings with voltage and field winding. The possibility of the AC voltage amplitude to be induced on the stator of one phase can only happen if there is no load. Also, if the windings became close to each other, then we will obtain the maximum inductance of the stator and field windings.

Field resistance and leakage inductance in the stator are responsible for entering the values referred to the parameters into the synchronous machine.

By using transformation ratio procedure and knowing the nominal field current, we are able to calculate stator/field ratio.

In case the nominal field current is anonymous, the values can be computed by using field resistance and leakage inductances values in per unit.

The corresponding of the signal applied to (Vf) with the actual field voltage is due to the specification of nominal field current. By this process, the field current will be able to identify the actual field current (If) in the output measurement.

The signal produced into (Vf) will match with the stator’s actual field voltage if the nominal field current is not specified, and this process will lead to the production of nominal stator voltage by the nominal field voltage. The output measurement will give the value of the field current into the stator.

The normalization process made between the applied voltage (Vf) and the nominal field voltage in order to get an input value of 1 per unit and also to produce this value into the stator’s voltage at no load. The current (If) value is also given in 1 per unit value due to normalization with the nominal field current.

Simulink program allows to us to select different synchronous machine from the library, the main difference between these blocks is about the specifications contributed with the machine.

* SI fundamental block specifies the parameters such as resistance, leakage inductance, and alternate inductances in SI units of the stator, field, and damping windings. The values appointed at the parameters are the stator’s RL values, not actual field values.
* PU fundamental block specifies the rotor and stator side in per unit.
* PU standard block inputs are specified by either standard or operational parameters.

Due to the usage of software that is contributed to the power analysis, the equations of the synchronous machine are computed by using a certain mechanism called direct-quadrature-zero transformation. The normalized per unit parameters are responsible for making easy calculation process, such as in PU fundamental; the process of equations calculation is done from the given data. The action contributed to the SI fundamental is done under transferring the parameters of the rotor side to the stator side. The process of data translate is for PU standard block is done by translating the parameters from fundamental to standard. The translation process also has the ability to make translation of parameters from fundamental to operational.

Preset model gives parameters of the mechanical and electrical rates as (KVA) for power, (V) phase-to-phase voltage, (Hz) frequency, and (rpm) rated speed.

For entering the electrical and mechanical parameters in the dialog box, we should select one preset model corresponded to mechanical and electrical parameter.

The variation among the inputs and outputs of the synchronous machine is referred to the dialog box that we chose the parameters from, and that’s due to the specification of the chosen type of the machine. In case the chosen parameter in SI unit, then the inputs and outputs are also in SI.

Diagram, engineering drawing

Description automatically generated

Figure ‎2.12: Synchronous Machine Block

Input and output ports of the synchronous machine are stated as follows:

Pm: this is the machine’s shaft mechanical power either in Watts or in per unit value. The stated input can be either function or positive constant in case of generating mode, and function or negative constant refers it to be in monitoring mode.

W: this is a reference for the speed of the machine with SI unit (rad/sec).

Vf: this input is for the field voltage, if the voltage regulator is in generator mode, then the voltage is supplied, and if it was in motor mode then it will have the possibility to be constant value.

M: this is output port refers to a vector, but this vector contains measured signals.

**Excitation**

The main functionality of the excitation block is to produce the required regulated field voltage to the synchronous machine by modeling the driving a diode rectifier in the AC alternator. The regulator of non-controlled voltage produces the voltage value in per unit by the diode rectifier when lowering the limit of zero.

The input and output ports of the excitation block are consisted as follows:

* Vref: is the stator terminal voltage reference value in per unit.
* Vt: The stator terminal voltage value of the synchronous machine that is measured in per unit.
* It: The stator terminal field current value of the synchronous machine that is measured in per unit.
* Ifd: this input is designed extra to excitation block, but it connected to a terminator block in order to prevent the warning of the unconnected output signal.
* Vstab: This input ensures the stability to the power system, so connected it into ground block.
* Efd: It is output port that provides the required field voltage to the synchronous machine.

The parameters of the excitation block consist of several selections values and internal limits as seen in figure 2.14 below.

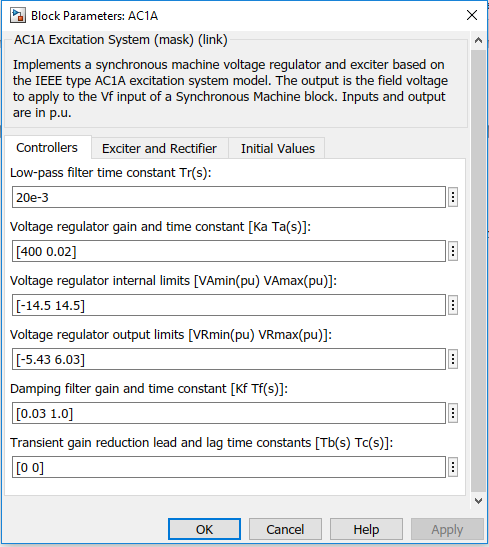


Figure ‎2.14: Excitation parameters

For controllers’ tab:

* Low-pass filter time constant is responsible for the representation of the stator terminal voltage transducer by the first order system constant time (Tr).
* Voltage regulator gain and time constant represents the main regulator by a certain gain (Ka) and time constant (Ta).
* A voltage regulator internal limit is simply responsible for the limitation of VAmin and VAmax in per unit value.
* A voltage regulator output limits is also responsible for limitation procedure of VRmin and VRmax.
* Damping filter gain and time constant is the representation of the derivative feedback by (Kf) as gain and (Tf) as a time constant.
* Transient gain reductions lead and lag time constants is the representation of the lead-lag compensator by the first order time constants (Tb) and (Tc).

For exciter and rectifier tab:

* Exciter gain and time constant represents the exciter by the first-order system of specified gain (Ke) and time constant (Te).
* Exciter alternator voltage value represents the saturation by increasing the requirements of the exciter’s excitation. By specifying the two voltage points Ve1 and Ve2 in per units we can have the action of saturation.
* Exciter saturation function values acts the same as the alternator voltage but the difference is that the values for this blank is field current on no load and field current on the air gap which is (SeVe1) and (SeVe2).
* Demagnetizing factor is responsible for the functionality of every alternator reactance by specified gain (Kd).
* In order for the rectifying loading factor to be appropriate with commutating reactance, we represent it by gain (Kc).

**Diesel Engine Governor**

The entire implementation associated with this block is associated with diesel engine and governor system. Although there are two inputs in the diesel engine governor block, but the inputs are related to each other with different functionality. The first input is responsible for the reference speed and the second input is for the measured speed. This process is made for obtaining an output of diesel engine mechanical power. Any failure could happen by the motor it will affect the whole system of the generator and it will stop working.

The operation of this block is made by a specific transfer function and it is called a regulator, the equation of transfer function is:

Hc = K.(1+T3.s)/(1+T1.s+T1.T2.s^2) Equation ‎2‑3: Regulator Transfer Function

The throttle actuator also includes a specified transfer function for the implementation stated as follows:

Ha = (1+T4.s) / [(s (1+T5.s) (1+T6.s) ] Equation ‎2‑4: Throtle Actuator

Time delay (Td) function is for the representation of motor engine.

The connection of the two inputs is from different sources, the first input which is (wref) is connected from the output of the switch which is among three different input values two of them are constants, and this switch takes the information originally from the main source and the constants, after processing the result will be delivered into the first input (wref).

The second input (w) is associated with the connection of the excitation system inputs.

**General Expression**

By using specific function to this block, we were able to match the input dimensions and deliver it to the stator terminal voltage and stator terminal field current that are entering the excitation block.

**The Switch**

The implementation of the switch block is made under certain circumstances; usually the main procedure is made through the second input, the value entering make a comparison with zero, if the value entering the second input is equal to zero, then the switch will activate the third input to pass through the output wire which is usually connected to a constant value, the other case in contributed to any value greater than zero then the switch will activate the first input value to pass through the output.

**Input and outputs of each generator.**

Each Generator subsystem receives an input from the automatic transfer switch that depends on the ATS values whether it is going to work or not. The Value coming from the ATS is first connected to a switch before going to the diesel engine governor, to guarantees only one or zero is being directed to the generator.

The output of the generator subsystem is consisting of the three phase wires that are flowing to the bus selector that we previously stated.

The generators output is carrying the power that is set in each generator for 600 KW.

### The control units

The control units of the system are done by two devices block, the first block is the switch button, and the second is the control panel.

**Switch Button**



Figure ‎2.14: Switch button

The switch button block convey the idea of having different cases during the simulation process, which helps us to reach into a convenient procedure and knowing whether the generators will work properly or not and the most important case is to know what will happen when the main source suddenly fails to supply power to the load.

As suggested in figure 2.14 above, if we select on period, that means that the main source is supplying power, and if we selected off period then the main source will stop directly and the generators will begin working and supply the required power to the load.

The parameter of the switch button functionality is to connect a specific block by selecting the block that we will work on.

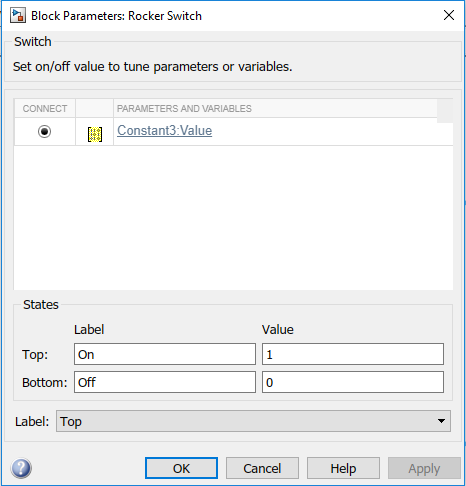


Figure ‎2.15: switch button parameter

After selecting the block, it will appear directly into the screen of parameter and we press connect option, the button’s connection with a constant number, and as seen in figure 2.15 above, the constant will change either into 0 or 1, zero means the main source is OFF and one means the main source is ON.

### Control Panel

The control panel is one of the most important part in any system, and that is why we paid a great attention to it after finishing the project, we designed it through MATLAB app designer to have a well-structured system environment. We also designed another way to control the system and monitor it through a remote control who is operating on web browser via the internet link, in the next lines we will show the functionality of both ways of controlling the system.

Chart

Description automatically generated

Figure ‎2.13: Control Panel

**MATLAB App Designer**

This control panel is designed in the MATLAB app designer with various functionalities to have full control on the system, in this control panel you can start, stop, pause, continue, or have a step forward in the simulation to the system, you can also control the switching between the grid and the backup generators. The coding is in the appendix section.

**Remote Control Via Internet Link**

This remote control was designed by three programming languages, they are HTML, CSS, JAVASCRIPT. The good thing is you are free to design the style and free to have personalized functions to apply as commands in the MATLAB command window, it is coded so it sends MATLAB commands through JavaScript to the MATLAB command window these commands are simulation commands, so it affects the simulation directly, below is the remote in the browser window.

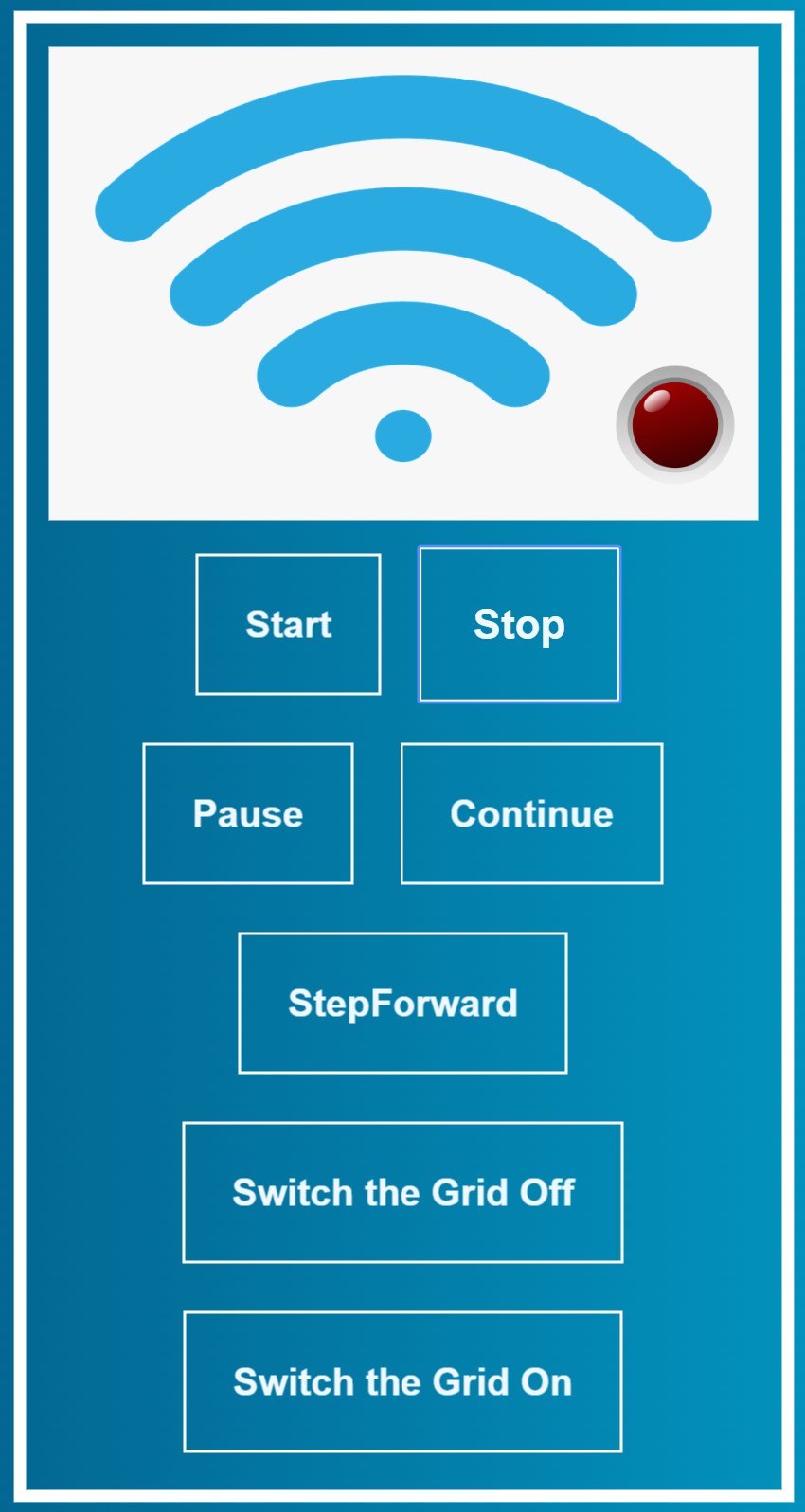


Figure ‎2.14: Remote Control Via Internet Link

### The measurments

In order to compute the measurements of the generators, main source, and the load, we need to insert specific blocks to be among them, the measurement is compiled with three components contributed to each other:

1. Bus Selector
2. GoTo tag
3. Three-phase Instantaneous Power

**Bus Selector**

Bus selector block is specified to give the output value from the input connection, the measurements done in the system is for knowing the voltage and currents.

Other important characteristic about the bus selector is that it doesn’t get affected by the change that could happen during process, but instead the changed value by the main source or generators gives the new values of the power.



Figure ‎2.16: bus selector

Figure 2.16 shows the connection between the inputs and outputs of the three-phase system.

The parameter of the bus selector helps us to label the needed signal for voltages and current, and also we have the ability to choose the type of the measurement for the voltage, so we chose phase-to-ground type as seen in the figure 2.17.

**GoTo Tag**

The main function of goto tag block is receiving the signal from the specified bus selector. In order to get the visibility of the tag, we should define the tag as scoped inside the block, and then by using goto tag we can get the result. By updating the diagram, the selected tag name will be displayed by the block icon.

The parameter of this block is fully associated with the goto tag block as seen in figure 2.17 and figure 2.18 below.

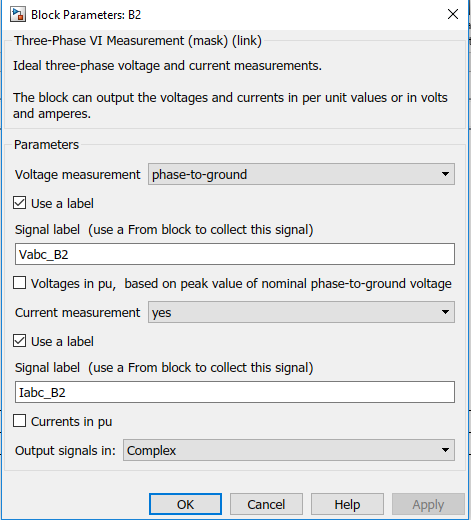
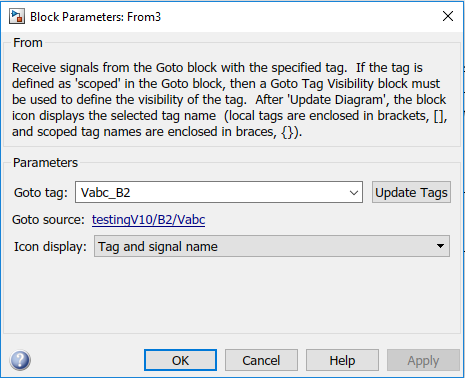


Figure ‎2.17: bus selector parameter Figure ‎2.18:GoTo tag parameter

By selecting the name of the signal inside the bus selector, we should the select the same name for the goto tag block in order to get the measurement need for the output of the supplying block.

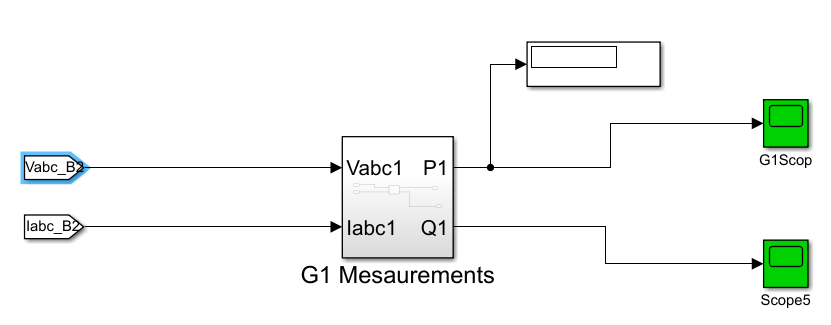
**Three-phase Instantaneous Power**

This block in general defines the active and reactive power in terms of periods of the voltages and currents.

For having a balanced and harmonic-free voltage and current the instantaneous reactive power should be accurate.

The current flow procedure will lead to producing positive active and reactive power.

This block doesn’t contain a parameter but instead, it just computes the values and delivers it to the output wires.

Figure ‎2.19: entire measurements

As we can see from figure 2.19 above, the whole process of the measurement is done through the three-phase instantaneous power block which is named as G1 measurements, and this done is made for every generator and the main source.

G1 measurement can give us the result of the power in watts and reactive power in Var.

We can have the results delivered into the display block which gives us the result as numbers or we can have it as signal delivered to the scope.

# System model and Work Done

In this section we will talk about everything we did in the project from a practical view.

First, we will show the model of the system in Simulink in order to conceptualize and construct the system, by having the modelling for the system it’s easier to analyze and understand how the system works.

## 3.1 System Model

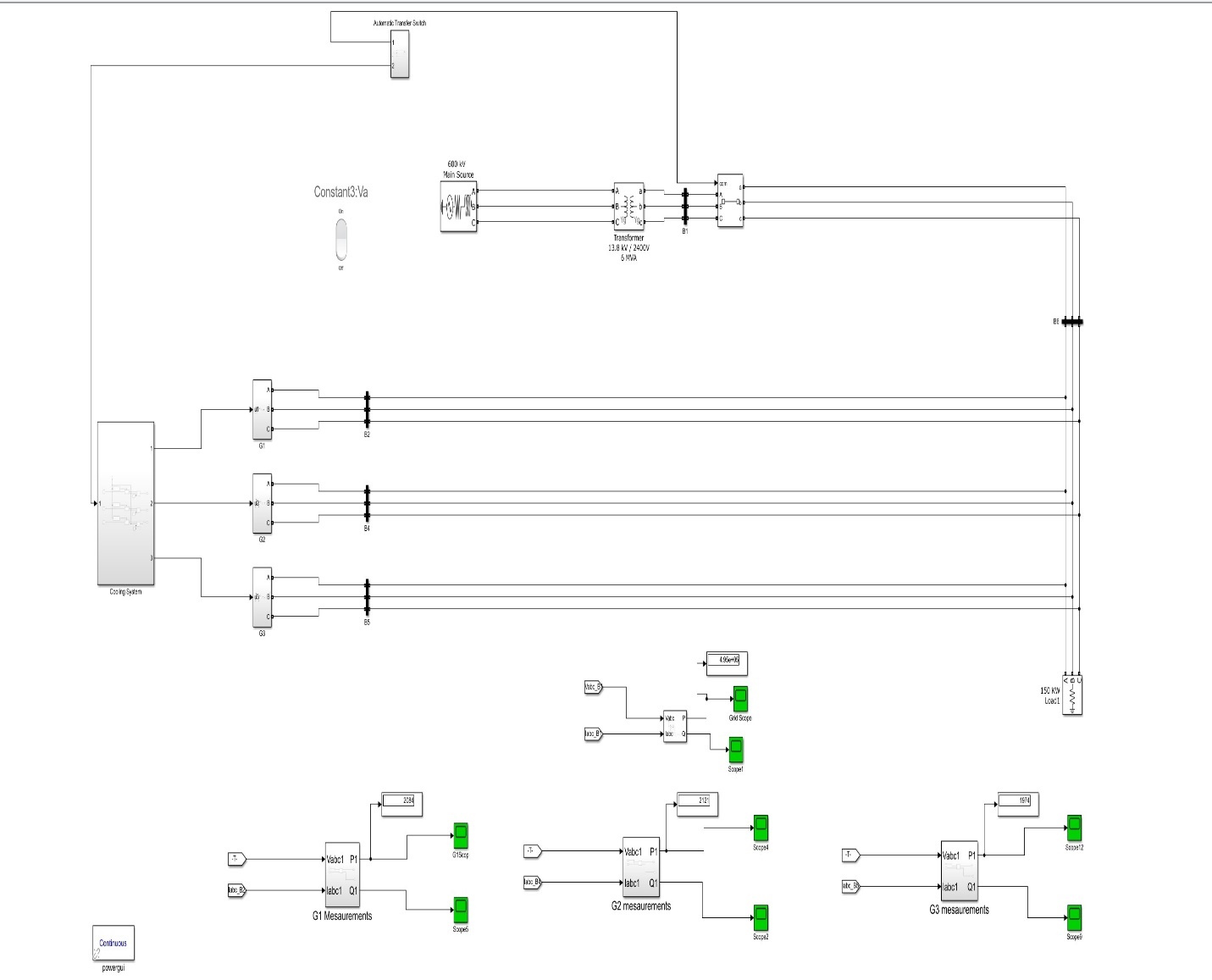


Figure ‎3.1: System Model in Simulink

### System Model and analysing

Having a well-structured system was our main goal from day one in working in the project. We managed to structure the project into subsystems, each subsystem contains its circuit and blocks that leads to a particular function or result, as example the subsystems we have in the project are:

* Automatic transfer switch
* Cooling system
* Generators
* Measurements of each generator
* Control Panel in MATLAB Application Designer

In figure 3.1 above it shows the design of the system with all subsystems and connections between them.

Everything should be analyzed logically so you can work very clearly in order to achieve your desired goal at the end of any project.

The system is modelled into many sections and every section contains several blocks so each section implements a specific function such as the grid section, the Automatic transfer switch, the cooling system, the backup generators, the measurements section, and finally the load.

Then analyzing each section will make the understanding for the required function is easier and simpler, next you would start looking for the blocks you need to implement such function

## 3.2 work done

The work done part will be divided into 2 parts:

1. The design of the system
2. The simulation and its result

### 3.2.1 System Design

The design of the system was incredibly challenging at the beginning, looking for the right components to use, where to use them, and where to connect them and what would be their parameters.

First, we started by breaking the whole projects into small milestones, so we understand clearly what we need to do till we achieve that milestone.

We started by the main source of the system what it would be and what component to use to achieve the idea of main source (Grid), as well as the backup generators.

How we are going to represent a backup diesel generator, and the ATS, the cooling system, the load of 500 KW, and the control panel or even the remote control to control the system via the internet link.

Listing all the needs is a step of finding the solution process. Finding what you don’t have makes you know what you need to have in the end in order to make something works for you.

In the next pages we are going to list the components and the parts of the system to show them in action.

**Design Criteria**

* Three Synchronous Diesel-powered generators with 600 kW power generation
* Critical Load with 500 KW
* Primary Source (Mains)
* In case the mains have failed, the generators shall supply, the power to the load and distribute the load equally among themselves.
* In case one or more of the generators fails/become operational again.
* the working generators shall redo the load balancing.
* When the mains power becomes available, the generators shall stop.
* All the generators should operate synchronously.
* By every 8 hours, one generator should stop and cools the machine.

First let us start with the **main source**.

**Three Phase Source**

**To have a Three-Phase Source** which is necessary to implement the main source of electricity in any system. And that was a key block in our system design criteria, in the next lines we are going to talk about three-phase source block as we used it exactly in the design.

Is the main power source in any building or facility, and we represented it by using the block in the figure below

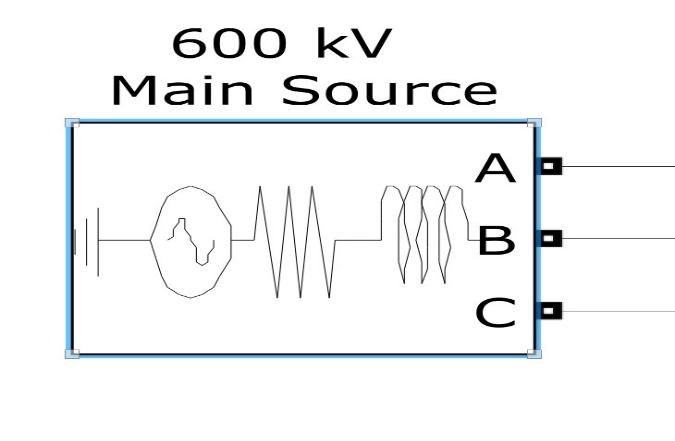


Figure ‎3.2:Three Phase Source Block

The three phase source is acting like grid and it can have either of two states on or off and this is controlled through the control panel we designed either by the MATLAB app designer or the remote control via the internet link.

**The Diesel Generator**

In our system we designed three diesel generators based on our design criteria, in the next lines we are going to show the generator components in the design.

The main goal associated with the diesel generator is to supply the needed power to the load, of course in case the main source failed to supply. Although the diesel generators have the ability to supply 600 KW in our project, but the critical load power is only 500 KW, so the generators simply supply the specific amount needed. Due to a condition of having three of them in the system and all of them should operate under certain conditions, the amount of supplying power will be distributed to the critical load with balanced amount among them. In case any failure occurred to the system, the generator that is operating and working will understand the entire situation and will begin functioning at different amount in order to make the complete entire procedure of the system without any losses.

The figure below illustrates the whole operation done inside the generator’s subsystems.

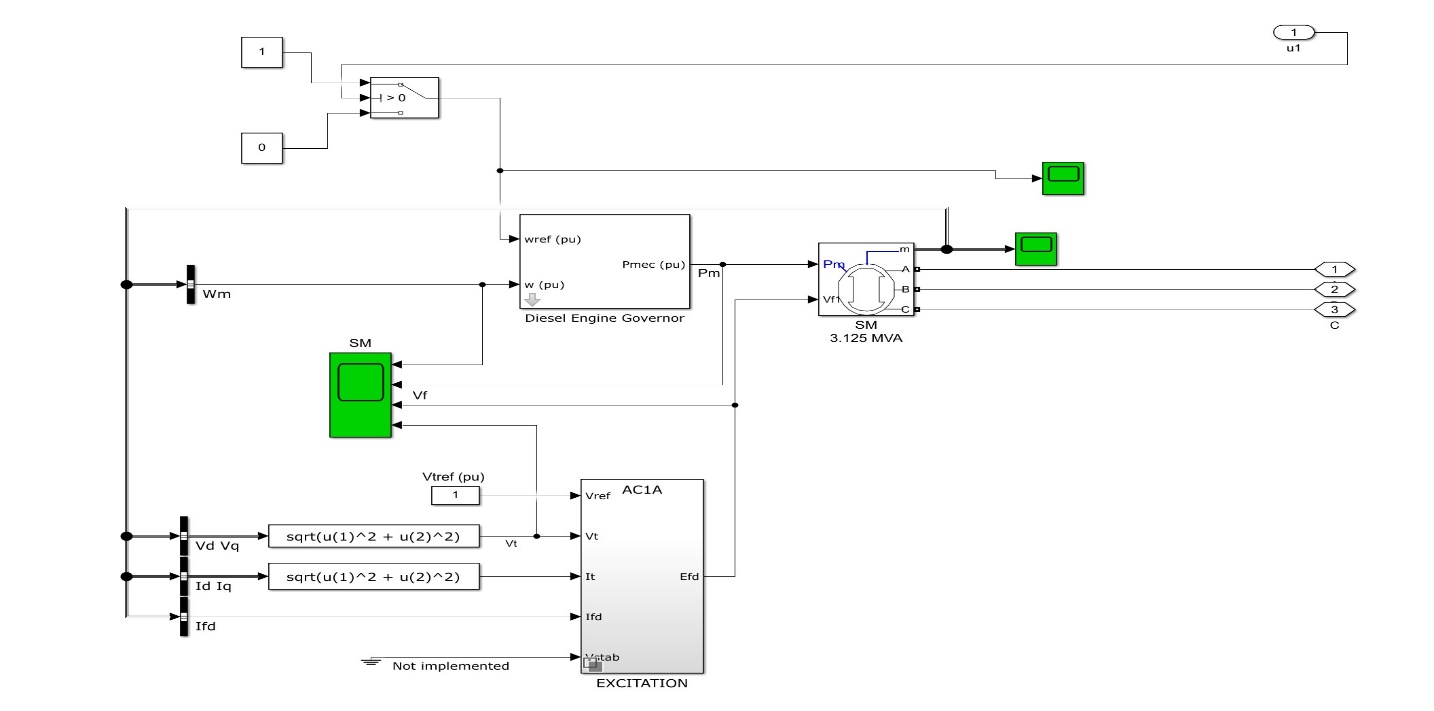


Figure ‎3.3: Diesel Generator Unit

The Work of this diesel generator unit is to produce 600 KW active power, for more obvious information listing we will show the blocks parameters and configurations.

The diesel generator is consisting of

1. Diesel Engine Governor
2. Synchronous Machine
3. Excitation System

**Diesel Engine Governor**

It is necessary to automatically adjust the fuel being supplied to the engine and to adjust the power and speed of the generator, it is the engine that make the whole generator work alongside with the synchronous machine

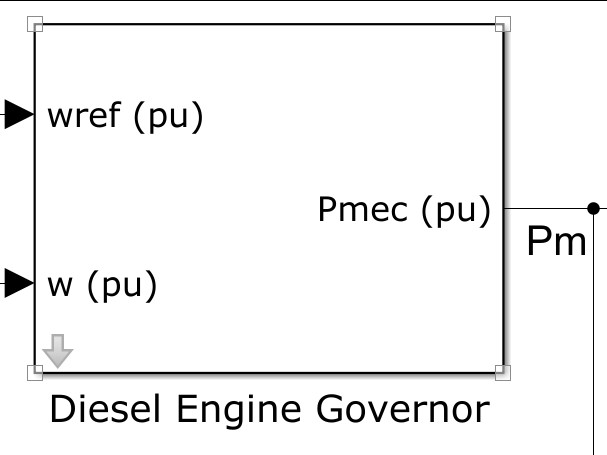


Figure ‎3.4: Diesel Engine Governor

The Governor referred in the above figure is one of the diesel engine parts, this governor is one of circuits required to control the fuel being injected to generator to ensure best condition at different values of speeds and loads within the range stated. The functions of the governor is to regulate the speed of an engine, when there are any variations of the load value.

**The Cooling System**

The cooling system is what guarantees the most efficiency to the entire system through alternative operations to the generators.

In this section we will talk more theoretically about the cooling system, later on the work done chapter we will talk more practically about it.

The cooling subsystem connected to the three generators to control their operation time.

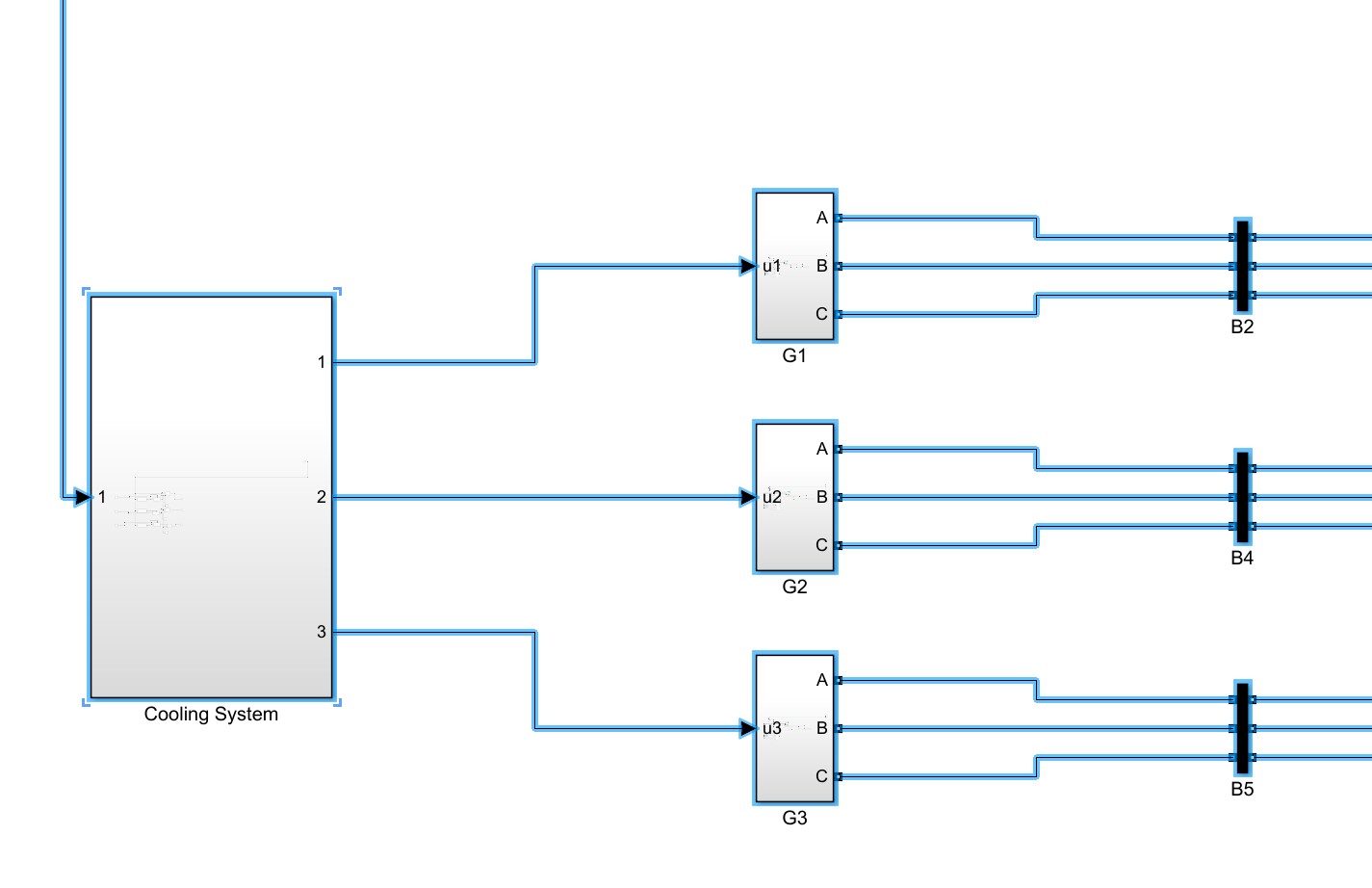


Figure ‎3.5: Cooling Subsystem Connected to Generators

The cooling system is inside a subsystem in order to have a well-structured system and make the system looks simple to the eye, all the theoretical parts were stated in the theory used section

### System Simulation

Simulation of a any system is the operation of a emulating in terms of time to graphically showing changes according to some design criteria and based on the factors selected in the design criteria the system should be designed, which helps analyze the performance of an current or a proposed system. In different words, simulation is the technique of the usage of a mannequin to find out about the overall performance of a system. It is an act of using a model for simulation.

Several selections among the general design especially in parameters of the block have a contribution with the simulation process in a way or another.

The important characteristic associated with the simulation process in the entire system is having the possibility of simulating under several circumstances, and this advantage came from the blocks by containing certain functions related to the control of the blocks, and the other advantage is simulating the entire system under chosen time in seconds. In other word, once we click on the run command from the tab in the upper screen, the simulation operates within a specific time as given in the upper bar of the screen, and this is important for our system in order to get high efficiency, ordinary values, and maintain the stability till the end of the limited time. In order to get the needed results in general through the simulation procedure, we need to fill the blank referred to stop time, which is located at the left side of the run button, with at 24 seconds of the time, which is basically an analogy into 24 hours.

Now let’s talk about the several cases that could happen in general which some of them view the changed result by the display and scope block.

The first case that happen at the beginning of the simulation is having the main source (grid) operating and able to supply a 500 KW to the critical load as seen in figure below, at meanwhile the generators will be almost zero and no distribution of power is among them also seen in figure below.

The second case is making the main source (grid) stops at any time of the 24 seconds during the simulation, and this leads the generators to begin functioning. This case is contributed with the switch button which is connected to a constant value that represents the situation of the main source, as we said before, ON represents the action and OFF as nonfunctioning. After the main source is completely shut down, the automatic transfer switch will be activated and quickly delivers signals to the three generators to begin operating.

The connections of the cooling system outputs into the generators inputs will state each situation of every generator through the 24 seconds.

The source components connected in the interior block of the cooling system is sequence block, there are three of them with each one delivering the specified case into a specific generator, and each one delivers certain order of functioning through time.

The time sequence of each generator is stated in the table below as follows:

Table ‎3‑1: Generator Operation Cases

|  |  |  |  |
| --- | --- | --- | --- |
| Time (sec.) | Generator 1 (KW) | Generator 2 (KW) | Generator 3 (KW) |
| 0 to 8 | 0 | 250 | 250 |
| 8 to 16 | 370 | 0 | 130 |
| 16 to 24 | 130 | 370 | 0 |

From the table above, by the time process in seconds and generators in kilowatts, we can see that every generator should have 8 seconds break for cooling, and also every generator will maximally operate for 16 seconds. By using this process, we are able to have a balancing distribution of the power among the generators by each one supplying 250 KW through whole day and importance of the critical load lies on the stability.

**Simulation Results**

First Case is from 0 to 8 seconds we have the first generator is off and the other two is on, each generator will distribute the load among themselves each one is having 250 KW.

As shown in the figure 3.6 the first 8 seconds are achieving the first case, after the 8 seconds we notice the system changes to the second case.

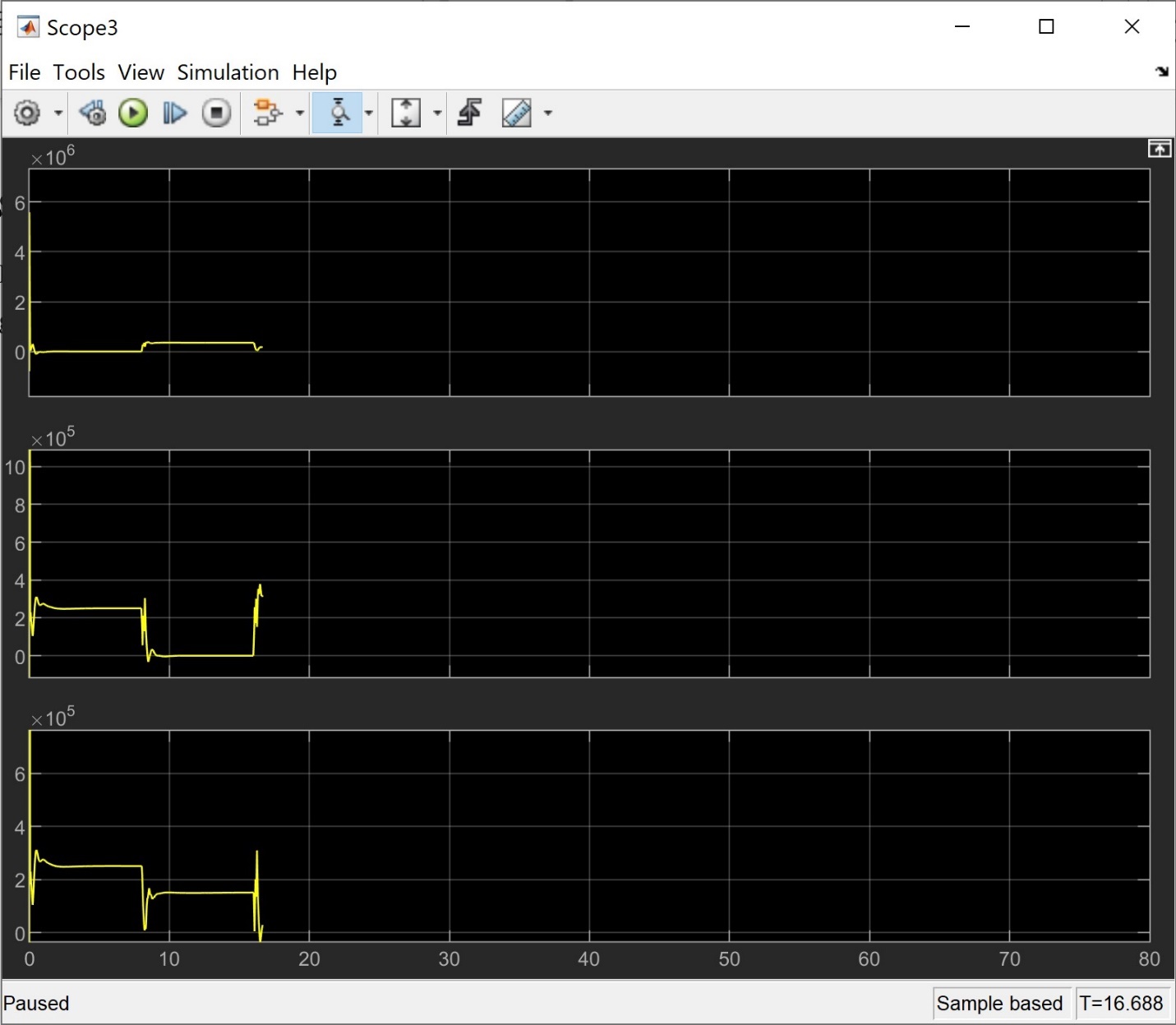


Figure ‎3.6: Case 1

Second Case is from 8 to 16 seconds and we have the first generator is on with 370 KW, the second is off, the third is on with 130 KW, the third case is showing in the following figure.

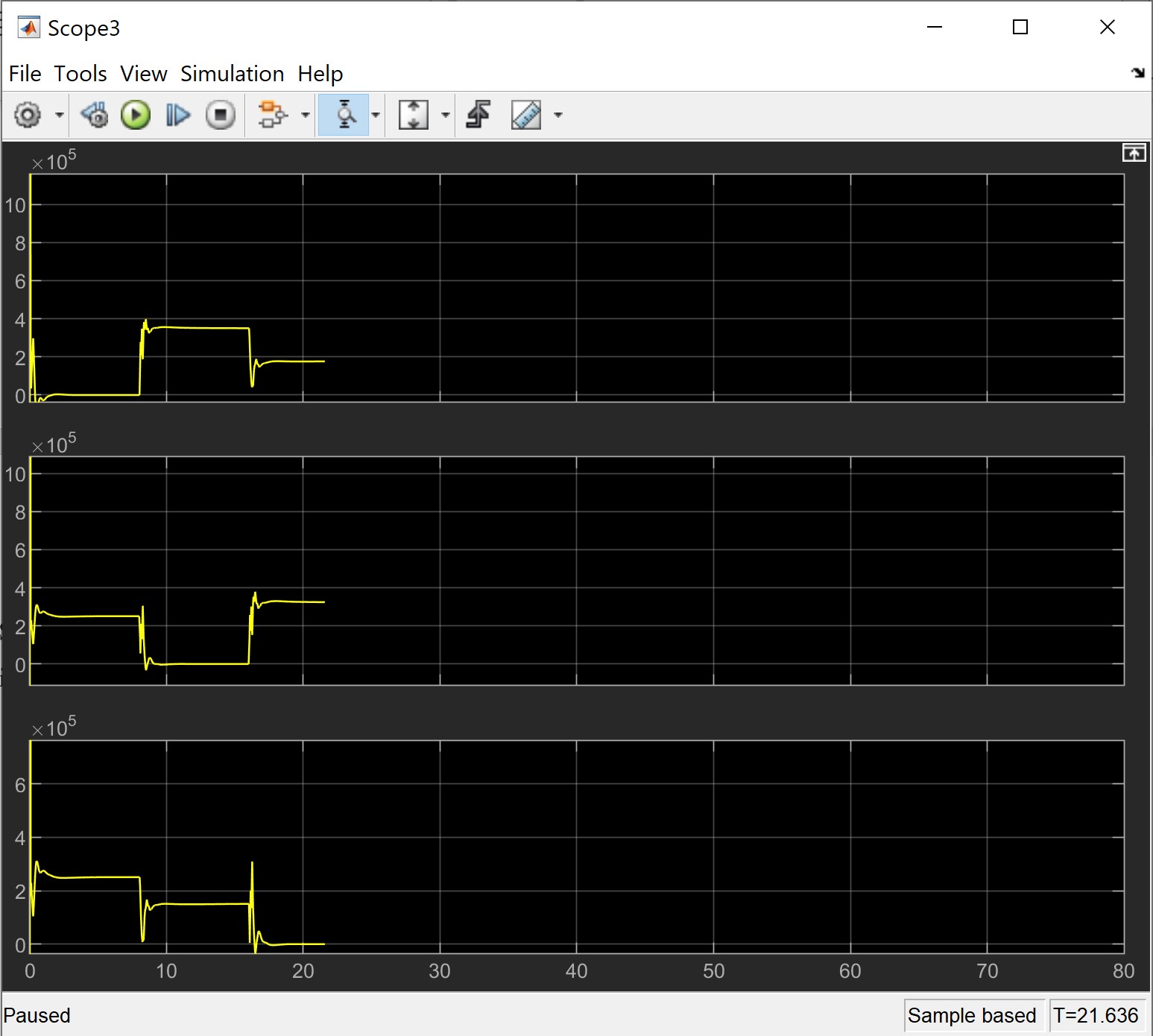


Figure ‎3.7: Second Case

Third Case is from 16 to 24 seconds, when the first generator is on with 130 KW and the second is on with 370 KW and the third generator is off. The result of this case is showing in the following figure.

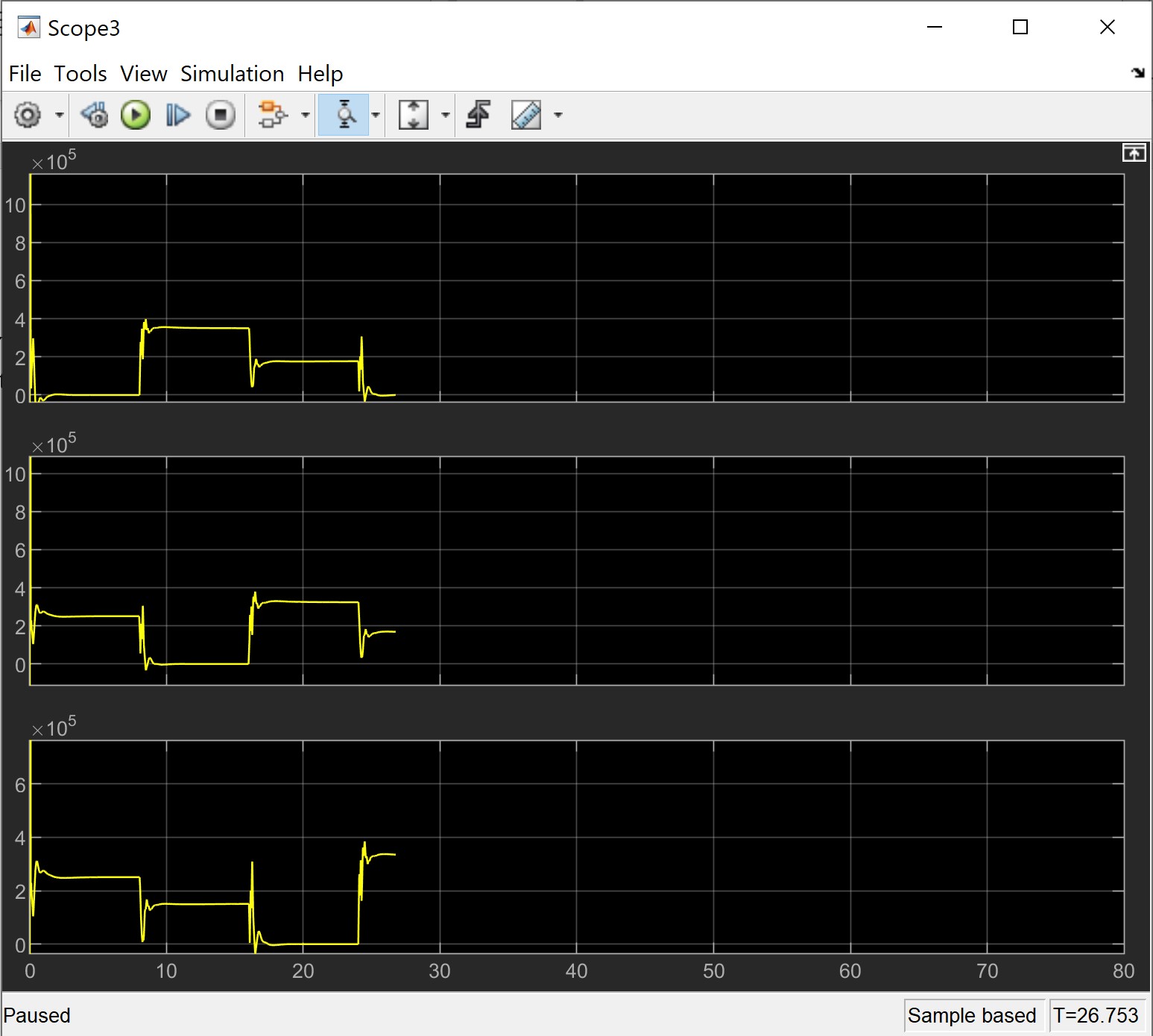


Figure ‎3.8: Third Case

As we stated in the previous pages the whole cases of switching the operation time of each generator and it is working perfectly as required based on the design criteria.

Next, we will show the case of switching between the grid and the generators, first the system was working on the power of the generators then after clicking on the switch that is connected to the ATS, the grid is on at the 18 second and supplying the values specified for the load as 500 KW.

The time response of the grid to get full stability is almost one and half a second which is perfect time response till stability.

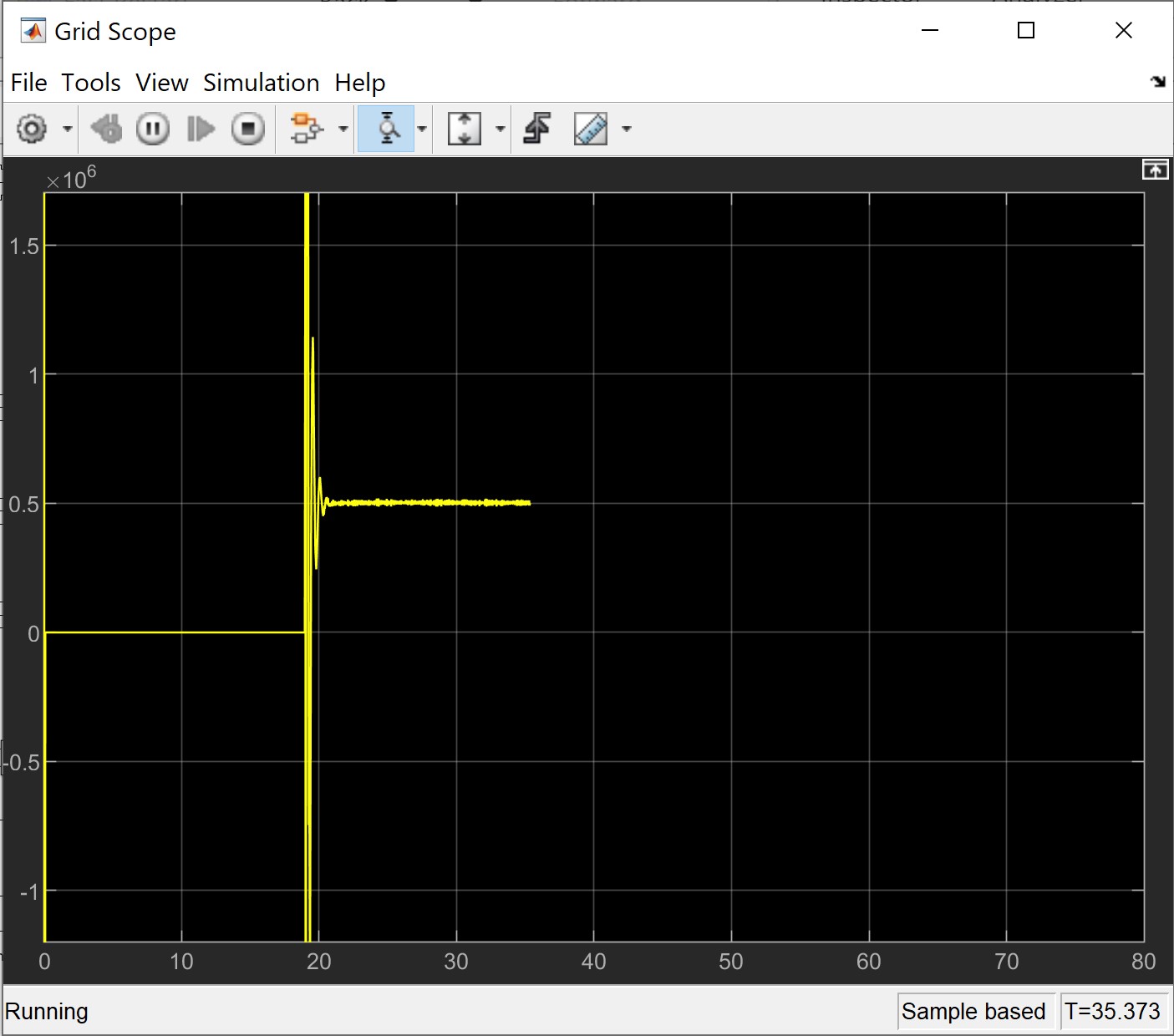


Figure ‎3.9: Grid on Case

Conclusion

The current community and environment are inextricably connected to its other half; energy. As a result, the importance of the backup power has recently become a high profile. Hence, in this report the backup power synchronous diesel generator discussed and depicted in details. This project is aimed to simulate and design a three synchronous backup power diesel generator that is connected to critical load such as; hospitals, plants, banks, etc. The project is composed of many parts to deliver the required power to the load. Each one of the diesel generators that has been used has a capacity of 600kw and the connected load’s capacity of 500kw. Also, there are three cooling units that connected to each diesel generator in order to maintain the temperature at a fixed range. In addition, there is an automatic transfer switch (ATS) that’s function is to switch the power source from the main grid power station to the backup power when occurring any outage to sustain the delivered power to the load. Furthermore, the safety measurements have been taken into account so the circuit breakers have been used to prevent any system failure. The synchronization process is considered in this research project in order to maintain the three back up diesel generator at the same phase and frequency so the load gain is at the same level. Furthermore, the mechanical parts; the governor and the exciter that used were essential since the exciter is mainly used to provide the main power to the electromagnetic that form the poles of the rotor and the governor’s function is to maintain the rotary speed of the motor within reasonably close limits. Also, the wifi feedback system has been used to receive and transmit the signal to monitor the working of the load and the backup power system. The monitoring system has been used and connected to the backup power generators to provide us with the updated results to sustain the electrical power. The diesel is used as a fuel power source to the generators since it’s burned at a high temperature so it provides the generators with more power and it’s more efficient compared to the other sources. In summary, this project has proven that it’s crucial not only luxury to use a backup power system to any critical load especially in these conditions since it doesn’t only cost money, but it highly costs more than that it costs people’s lives.

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# Appendix

**Code Of Remote Control Via internet link.**

<!DOCTYPE html>

<html lang="en">

<head><title>System Remote Control</title>

<script type="text/javascript">

function turnOn() {

// taking image in image variable

var image = document.getElementById('Image');

image.src = "green.png";

}

function turnOff() {

// taking image in image variable

var image = document.getElementById('Image');

image.src = "red1.png";

}

function holdlamp() {

// taking image in image variable

var image = document.getElementById('Image');

image.src = "yellow.png";

}

function Start() {

commandURI="matlab:set\_param('testingV10','SimulationCommand','start');";

document.location=commandURI;

turnOn();

}

function Stop() {

commandURI="matlab:set\_param('testingV10','SimulationCommand','stop');";

document.location=commandURI;

turnOff();

}

function Pause() {

commandURI="matlab:set\_param('testingV10','SimulationCommand','pause');";

document.location=commandURI;

holdlamp();

}

function Continue() {

commandURI="matlab:set\_param('testingV10','SimulationCommand','continue');";

document.location=commandURI;

turnOn();

}

function StepForward() {

commandURI="matlab:set\_param('testingV10','SimulationCommand','stepForward');";

document.location=commandURI;

}

function SwitchOff() {

commandURI="matlab:set\_param('testingV10/Automatic Transfer Switch/Constant3','Value','0');";

document.location=commandURI;

}

function SwitchOn() {

commandURI="matlab:set\_param('testingV10/Automatic Transfer Switch/Constant3','Value','1');";

document.location=commandURI;

}

</script>

<style>

body{

background: rgb(2,0,36);

background: linear-gradient(129deg, rgba(2,0,36,1) 0%, rgba(4,37,80,1) 0%, rgba(0,212,255,1) 100%);

}

form {

border: 5px solid white;

position: absolute;

top: 50%;

left: 50%;

transform: translate(-50%, -50%);

height: 620px;

}

.container {

padding: 10px;

}

.container .wifi{

width:300px;

height: 200px;

}

.container .lamp{

width:50px;

height: 50px;

position: absolute;

top: 145px;

right: 20px;

}

.row {

display: flex;

justify-content: center;

margin: auto;

}

div input.hvr-grow{

flex-direction:row;

margin:10px;

}

input {

padding:20px;

background: none;

color: aliceblue;

font-size: medium;

font-weight: 700;

border: 1px solid rgb(255, 255, 255);

}

.hvr-grow {

display: inline-block;

vertical-align: middle;

-webkit-transform: perspective(1px) translateZ(0);

transform: perspective(1px) translateZ(0);

box-shadow: 0 0 1px rgba(0, 0, 0, 0);

-webkit-transition-duration: 0.3s;

transition-duration: 0.3s;

-webkit-transition-property: transform;

transition-property: transform;

}

.hvr-grow:hover, .hvr-grow:focus, .hvr-grow:active {

-webkit-transform: scale(1.1);

transform: scale(1.1);

cursor: pointer;

}

</style>

</head>

<body>

<form name="remote">

<div class="container">

<img class="wifi" src="wifi.png" alt="">

<img class="lamp" src="red1.png" id="Image" alt="">

<div class="row">

<div class="start"><input class="hvr-grow" type="button" onclick="Start()" value="Start"></div>

<div class="stop"><input class="hvr-grow" type="button" onclick="Stop()" value="Stop"></div>

</div>

<div class="row">

<div class="pause"><input class="hvr-grow" type="button" onclick="Pause()" value="Pause"></div>

<div class="continue"><input class="hvr-grow" type="button" onclick="Continue()" value="Continue"></div>

</div>

<div class="row">

<div class="stepforward"><input class="hvr-grow" type="button" onclick="StepForward()" value="StepForward"></div>

</div>

<div class="row">

<div class="s\_off"><input class="hvr-grow" type="button" onclick="SwitchOff()" value="Switch the Grid Off"></div>

</div>

<div class="row">

<div class="s\_on"><input class="hvr-grow" type="button" onclick="SwitchOn()" value="Switch the Grid On"></div>

</div>

</div>

</form>

</body>

</html>