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PROTECTION AND DESIGN OF DISTRIBUTED ENERGY GENERATION SYSTEM

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Abstract—As penetration of distributed generation (DG) will increase at the distribution level, managing these structures effectively will become more and more challenging. One proposed way to manipulate these systems is via the adoption of microgrids. A microgrid is a distribution level community made of various masses and DG sources that function as a single aggregate load or generation source. Microgrids can either function related to the grid, or in the case of a grid fault, in an islanded mode. In this paper, we use Matlab Simulink's SimPowerSystems to model a small component of distribution network as if it have been a microgrid. We add a combine of renewable DG sources and one dispatchable source, which at maximum output can produce more power than the average microgrid load. We then simulate the four predominant fault sorts at every bus in both grid-connect and island modes and analyze fault currents and voltage ranges in order to decide how the safety scheme of the distribution network would need to be changed to facilitate microgrid functionality. We show that wellknown protection techniques are insufficient and advise the use of digital relays linked to breakers.

Index Terms— Microgrid, Protection, Fault Analysis.

I. INTRODUCTION

Due to the multiplied concern over global climate change, the demand for smooth sustainable energy sources has multiplied greatly. One of the principal problems with these sources, such as wind and solar, is integrating them into the larger strength grid. One proposed way is to have dispensed renewable technology sources integrated into a microgrid. A microgrid is defined as a low to medium voltage community of small load clusters with Distributed Generation (DG) sources and storage [1]. It can function linked with the larger grid or islanded in the match of a grid fault. A microgrid is managed via a single controller and is viewed as a single load or technology source through the larger system. It can be maneuvered in industrial, commercial, and residential areas. One essential assignment with working a distribution stage microgrid with Renewable Energy Sources (RES) related to the machine with inverters is safety against faults. In this paper we analyze fault currents on a large system of distribution network than that used in [1], [2]. Our gadget is included with a trendy distribution safety scheme. Our objective is to see how the safety will want to be modified to facilitate microgrid operation with the inclusion of DG sources and islanding capabilities. Our device was once built and simulated in Matlab Simulink's SimPowerSystems.

II. SYSTEM TOPOLOGY AND DG MODELS

A. System Description

A microgrid normally consists of small segments of a distribution community related to nearby DG devices and loads. The device used in this study is an 18 -bus community with a load ability of 3.03

MVA connected to a 10 MVA transformer. This device is the instance distribution system shown in [3] with line parameters and feeder supply impedance given. The phase loads of every bus had been also given and are proven in Table 1. The device is included the use of fuses and reclosers on the overhead traces and breakers on the underground lines. To this system we added four photo voltaic arrays, two wind turbines, and one diesel generator. The solar arrays are every related to three -phase inverters and grant a total of 2,256 kW. The wind turbines grant an additional 500 kW to the grid. During islanded operations, additional technology and load following is supplied via a 300 kW diesel generator. The one line format of the system is shown in Fig. 1.

TABLE I

Bus Loads For the Micro grid In Fig. 1, Blank Areas Indicate Unconnected Phases

	Phase A		Phase B		Phase C	
BUS	P (kW)	Q (kvar)	P (kW)	Q (kvar)	P (kW)	Q (kvar)
3	117	73	121	65	90	98
4	97	33	86	35	91	36
6	46	15	77	23	64	19
7	100	65				
8			85	32		
9					354	180
13	75	34	75	34	75	34
14	111	53				
15					176	34
16	89	63	89	63	89	63
17			314	126		
18	210	99				

B. Models of DG Sources

The inverter connected to the photo voltaic arrays is a current converter made with a three-phase IGBT/Diode Bridge managed through a PWM generator with a voltage/current controller. This is linked in series to an LC low-pass filter for increased power quality. An additional LC filter was once used in the enter to hold the fantastic of the dc input signal. The enter is any dc source rated between 50 kW and 570 kW and 5 kV. The output is a three-phase 12.47 kV system. Maximum allowable current is constrained to 90 A, about twice the maximum strength current. This is a version of the inverter used in [4].

The diesel motor model utilized in this study is a customized version of the one used in [5] and is connected to a 300-kW/12.47-kV synchronous generator Simulink block.

The wind mills are based on the wind turbine Simulink model tested in [6]. This turbine is linked to a 100-kW and 400-kW squirrel-cage induction generators. The generators are given steady wind enter needed for most capacity generation.

The representation for the PV modules is a simple single diode approximation with two resistors as shown in Fig. three This circuit is used to mannequin a Sharp ND-Q0E2U 160-W module with I-V traits bought from [7]. The resistor values are computed with the equations given in [8]. Though this mannequin is not the most accurate, we experience it is sufficient for this learn about as the present day limiting facets of the inverter will dominate the dynamics in fault simulation. This module mannequin is used to construct 564-kW arrays.

The DG sources are placed in appropriate areas, with the diesel generator providing a balanced three-phase load which will most in all likelihood be industrial and have a backup strength supply. The photo voltaic arrays are all, with the exception of the array at bus 12, placed with loads to simulate the combination effect of rooftop photo voltaic panels on houses and businesses. The wind turbines are positioned on buses barring loads as typically large turbines are positioned in wide open areas or hilltops close to transmission.

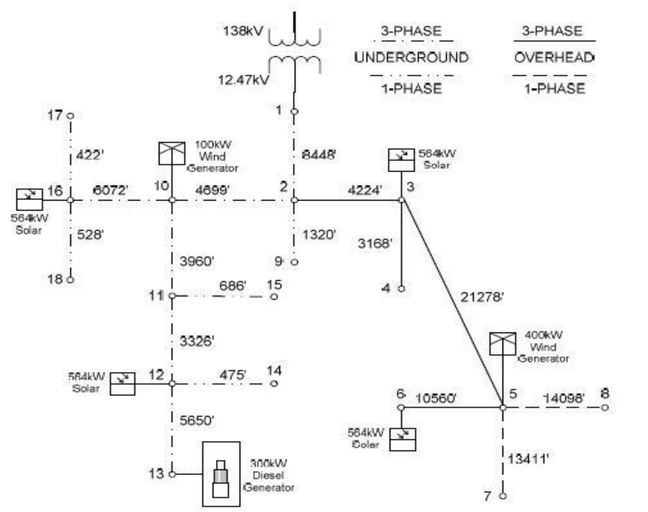

Fig 1

C. Modeling of PV Array

PV two arrays are two built up two with combined two series/parallel combinations of PV solar cells, which are usually represented by way of a simplified equivalent circuit model such as the one given in Fig. 4.1 and/or by way of an equation as in (1).

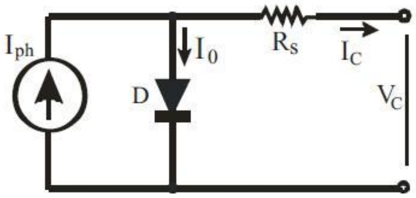

Fig. 2

The PV telephone output voltage is a function of the photocurrent that commonly decided by load contemporary relying on the solar irradiation level all through the operation.

Equation I

$$Vc = \frac{AkTc}{e} ln\left(\frac{Iph + Io - Ic}{Io}\right) - RsIc$$

A viable model of a photovoltaic array and inverter [4] was researched. After verifying the principle its points had been modeled in Simulink. This proved moretime consuming and intricate than intended. Like the theory, the mannequin labored both beneath load and no load conditions. Figure 3.4 suggests the model of the PV array system. The blocks of mostinterest are shown on in the top layer as viewed in the layout

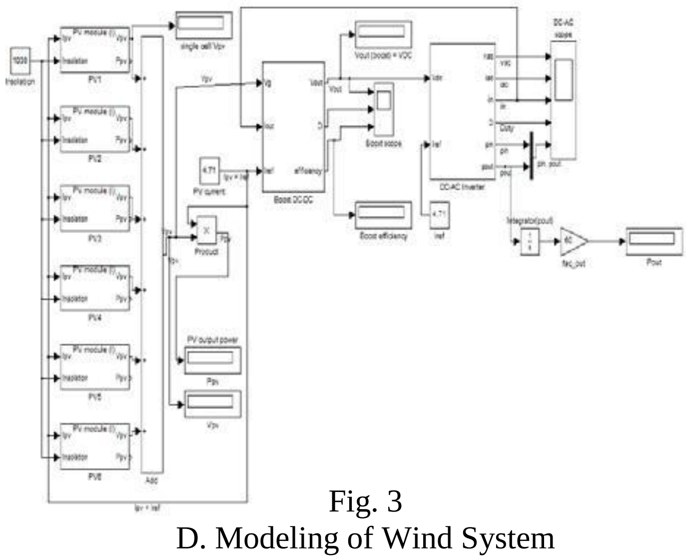

Fig. 3

D. Modeling of Wind System

A widespread model of the High-Penetration, No Storage, Wind-Diesel (HPNSWD) machine is as proven in fig below. This machine presented in this makes use of a 480 V, 300 kVA synchronous machine, a wind turbine driving a 480 V, 275 kVA induction generator, a 50 kW patron load and a variable secondary load (0 to 446.25 kW). At low wind speeds each the induction generator and the diesel-driven synchronous generator are required to feed the load. When the wind strength exceeds the load demand, it is possible to shut down the diesel generator. In this all-wind mode, the synchronous machine is used as a synchronous condenser and its excitation gadget controls the grid voltage at its nominal value. A secondary load bank is used to adjust the device frequency with the aid of absorbing the wind power exceeding client demand.

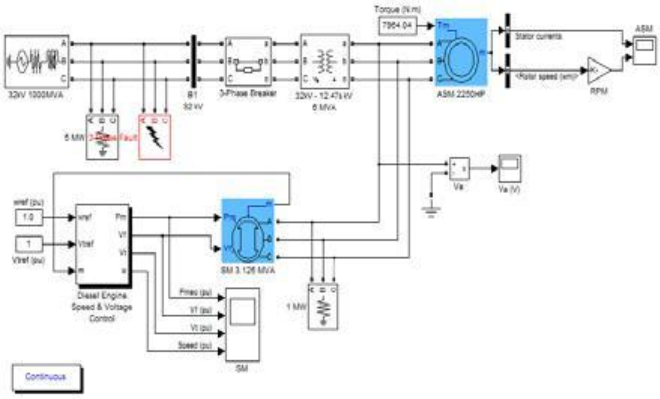

Fig 4

E. Modeling of Diesel System

A plant consisting of a resistive and motor load (ASM) is fed at 12.47KV from a distribution 32 kV community through a 6 MVA 32/12.47 kV Wye-Delta transformer and from an emergency synchronous generator/ diesel engine unit (SM). The 32 kV community is modeled by means of a easy R-L equal source (short-circuit degree 1000 MVA) and a 5 MW load. The asynchronous motor is rated 2250 HP, 2.4 kV and the synchronous computer is rated 3.125 MVA, 2.4kV. The SM excitation is carried out by using the widespread excitation block supplied in the computer library. The diesel engine and governor gadget are modeled through a Simulink® block. Initially, the motor develops a mechanical strength of 2000 HP (1.49 MW) and the diesel generator is in standby, presenting no energetic power. The synchronous computing device excitation machine controls the 2400 V bus B2 voltage at 1 pu. At t = 0.1 s, a three-phase to ground fault takes place on the 32 kV system, inflicting opening of the 32kV circuit breaker at t = 0.2 s

F. Matlab Model for Microgrid

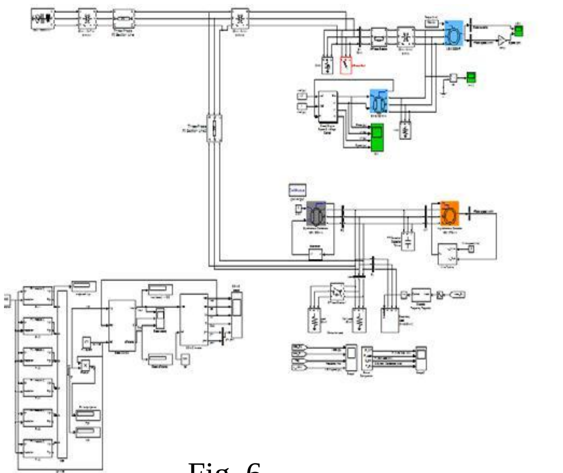

Fig. 6

In this study, we are involved in evaluating the maximum and minimal fault currents at each bus in the microgrid. The device was once built in Matlab Simulink the usage of the SimPowerSystem toolbox. The device is simulated the use of Simulink's ode3 with a fixed time step of 1 microsecond. The four

principal faults—single line to ground, line to line, double line to ground, and three section faults—are initiated in the system 0.1 2d after the system had reached regular nation and is sustained for every other 0.4 second. This allows the rms values of the symmetric fault currents to be measured. The fault impedance is chosen as 1mΩ. The device is solely simulated in the islanded mode as the fault currents at each bus for the unique machine configuration are given in [3]. Liability with DG source contributions in grid-connect mode can therefore be easily computed using superposition. Fault currents are measured on both the excessive (closest to substation) and low (farthest from the substation) side of the fault as most locations had generation on both sides. Currents are additionally measured at the excessive and low buses, (where excessive and low imply the identical as above) that would want to have backup protection if the devices at the precise bus have to fail.
Additionally, a three segment energy go with the flow learn about is conducted for three cases: (1) on the unique system, (2) on the grid linked microgrid system, and (3) on the islanded gadget with the utility system remoted to evaluate the operating currents with the fault currents.

III. SIMULATION RESULTS

A. Photovoltaic Array System Results

For every energy source, the person components were tried separately, as seen in Figure 4.1. The beginning factor was modeling of the PV array. It was once challenging to precisely take a look at the man or woman factors earlier than the device was completed. However, when all factors have been executed it labored as expected. There was once some issues with the system which arose when a step in insolation was once utilized to the input of the array. Further lookup was once carried out to try and recognize why this was happening. As a result of the research, meticulous checking and testing, the blunders have been amended. The result is a system which very carefully resembles the favored device response [4].

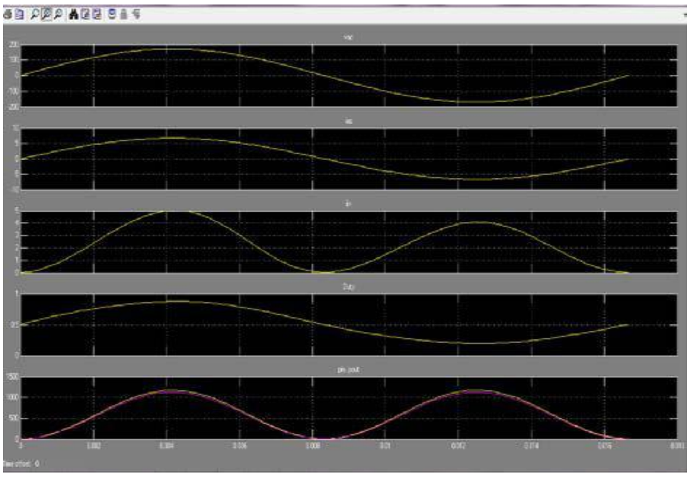

Fig 7

B. Wind System Results

The wind velocity (10m/s) is such that the wind turbine produces ample energy to furnish the load. The diesel generator (not simulated) is stopped and the synchronous machine operates as a synchronous condenser with its mechanical strength enter (Pm) set at zero. The example illustrates the dynamic overall performance of the frequency regulation device when an additional 25 kW customer load is switched on.

When simulation is run, voltages, currents, powers, asynchronous computer speed and device frequency on the two scopes are observed. Initial stipulations (x Initial vector) have been automatically loaded in workspace so that simulation begins in consistent state.As the asynchronous laptop operates in generator mode, its pace is slightly above the synchronous speed (1.011 pu).

According to turbine characteristics, for a 10 m/s wind speed, the turbine output energy is 0.75 pu (206 kW). Because of the asynchronous computer losses, the wind turbine produces 200 kW. As the major load is 50 kW, the secondary load absorbs a hundred and fifty kW to hold a steady 60 Hz frequency. At t=0.2 s, the extra load of 25 kW is switched on. The frequency momentarily drops to 59.85 Hz and the frequency regulator reacts to minimize the energy absorbed by way of the secondary load in order to convey the frequency back to 60 Hz. Voltage continue at 1 pu and no flicker is observed.

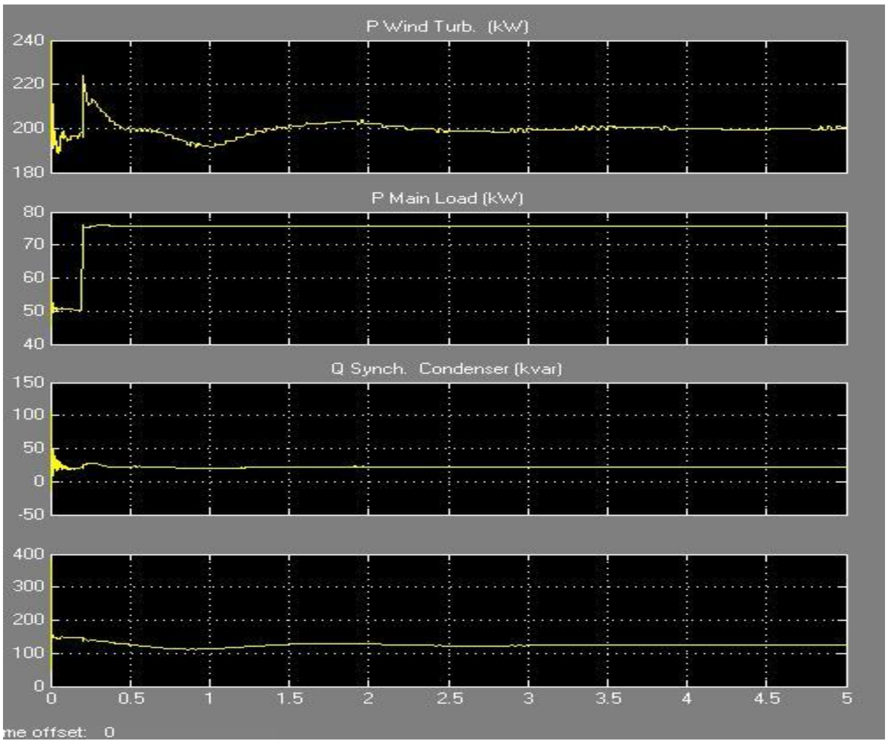

Fig 8

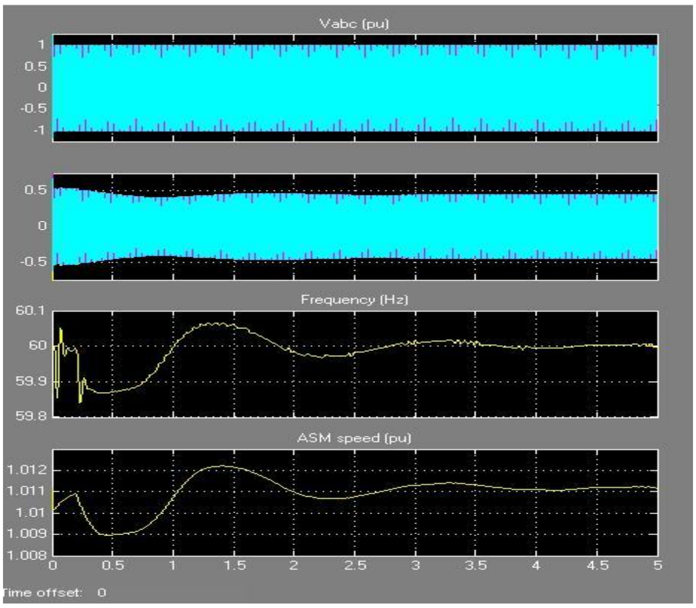

Fig 9

C.Diesel System Results

In order to start the simulation in steady-state, the synchronous computing device and the asynchronous motor for the desired load float is initialized. Specify the desired values by way of entering the following parameters:

Load Flow : U AB (Vrms) = 2400 , P (Watts) = 0 Specify also the ASM mechanical electricity by entering Pmec (Watts) = 2000*746.

Once the load waft is solved, the three line-to-line laptop voltages and the three computer currents are updated. The SM reactive power, mechanical energy and area voltage are displayed: Q = 856 kvar; Pmec = 844 W (power required by using resistive losses in stator winding); discipline voltage Ef = 1.4273 pu; the energetic and reactive powers absorbed by the motor, slip and torque are also displayed.

The diesel engine governor and SM excitation machine comprise integrators and transfer features which have also been initialized by using the load flow. The preliminary mechanical electricity has been automatically set to 0.00027 pu (844 W) . The preliminary terminal voltage Vt0 and field voltage Vf0 have been set respectively to 1.0 and 1.4273 pu. The cost of the steady block related to the torque enter of the asynchronous motor has additionally been robotically set to 7964 N.

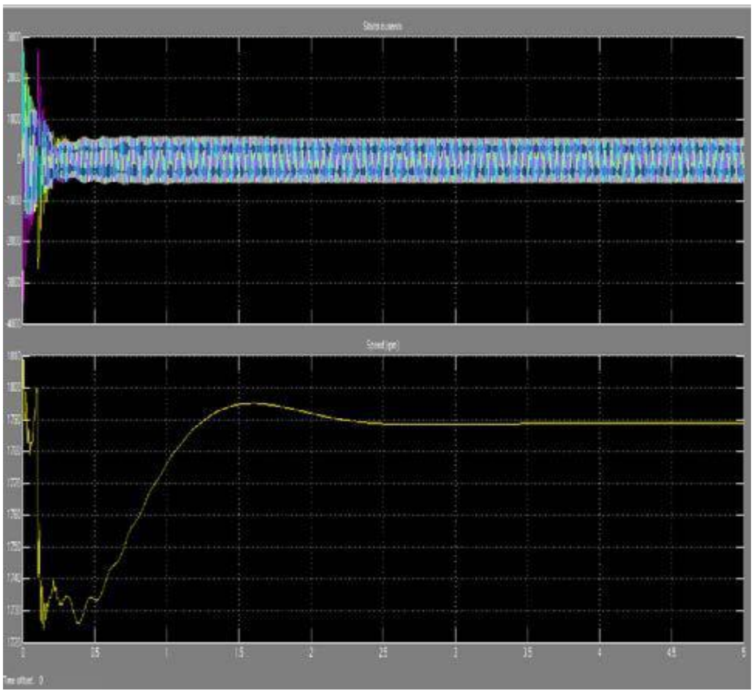

Fig 10

IV. CONCLUSIONS OF MICRO-GRID MODELLING

In this closing chapter the project plan, goals and effects will be highlighted and summarized. The assignment is mentioned in terms of what it objectives and how it could make a contribution to the energy industry's needs. It also explores how the task may want to be prolonged or extended and how this may be done. This consists of what can be executed in the future to apprehend micro-grid behavior, with the goal of micro-grids use and commercial development.

A. Project Conclusions

It is hoped that, by way of making use of the small and diverse sources which include it, micro-grids may also be capable to make a considerable contribution to the strength technology and distribution market For instance, if the sun is out the PV array may supply power, if it's windy the wind turbine, if it is neither or if extra power is needed, mains provide can be used. The inclusion of batteries in a micro-grid system would also allow excess strength produced to be stored, or alternatively the extra electricity may want to be put into the principal grid.

In this way it is predicted that micro-grids may want to limit air pollution and supply reliable energy in a range of conditions as discussed. Micro-grid conduct is on the complete not well understood. For this cause this assignment aimed to increase models suitable for analysis and investigation. The assignment aim used to be to model conduct of micro-grid's person electricity sources, and time permitting a micro-grid system.

A closing purpose was once to lay groundwork which would permit evaluation for the similarly improvement of a extra state-of-the-art model. More specifically, it concerned modeling a photovoltaic cell, a wind turbine. To this end the task has been successful. All models developed will permit for investigation that will furnish an appreciation of micro-grids to facilitate the evolution of a greater sophisticated model.

This mission was once carried out through way of tremendous research, mannequin design, modelling, trying out and development. Each strength supply model used to be carried out independently beginning with the PV array.

The PV array mechanism as predictable fora changing input. This is a precise result that reflects real situations well. The wind is now not yet utterly completed. The consequences hence some distance are very good, and it is anticipated they will improve prior to open day through further checking out and development. These sources will be related together to form a micro-grid. It is anticipated at least two of the three power sources will be related collectively to energy a single load.

B. Micro-grid Modelling and the Future

As in the past discussed, the desires of this assignment had been prescribed in phrases of how the model developed will be used. The next step need to be to in addition boost the micro-grid as a whole. It is vital to examine greater about how the sources engage with every other that is do they decorate or intervene with each other. More in particular their relationship to every other needs to be defined. I fall goes as expected and the micro-grid system as a whole is developed, the manipulate of the device will possibly be imbedded inside the electronics. It should be possible to use a specialized controller to get a more secure response and to use each electricity source greater efficiently. This have to absolutely be researched and regarded once the energy sources interplay and relationship to every other and the mains has been defined.

Another factor that may want to be developed further are the character sources inside the micro-grid. This may want to manifest on two levels. The first is the consideration of different variables for each source. For example, wind speed is no longer viewed for the PV array and in some conditions it would show quite extensive .Also, working in pu is more suitable than proper values the full conversion of the wind system to pu would be useful. The different way is to hold the mannequin up to date with the technology. This capacity as science and engineering enhance more environment friendly technology the gadget have to be updated also.

In the region of PV arrays technological know-how is constantly altering and improving. As there are different strength sources being viewed for use in micro-grids there search and modelling of them will at some point be necessary. The sources being regarded consist of gas cells and batteries which supply electrical storage. They would want to go via the equal process used to improve the different models, and then be linked into the micro-grid system.

The closing necessary aspect is to achieve some proper micro-grid statistics (rather than information from person energy sources).Due to micro -grids being a very latest thought and therefore no facts being available. As research organizations race to strengthen correct fashions and put in force them this will change.

C. Final Remarks

On the whole, this project The Modelling a Micro-grid System has been two successful. Models which permit for investigation of the person electricity sources conduct have been developed and it is predicted that a micro-grid unit will be modelled prior to open day. The assignment used to be carried out two by means of two doing good sized lookup and two by using two the usage of two a two diagram system to two enforce each system individually.Testing and development via appreciation was also a enormous section of this project. The desires of this mission have been met and it is predicted in addition lookup and development will be carried out on the system, with the aim that micro-grids will be able to make a valid, greener, contribution to the world's developing power needs.

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