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SIMULATION OF HYBRID MICRO-GRID WITH PV, WIND AND MICRO-HYDRO USING D-ELC IN AN ISOLATED SYSTEM

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ABSTRACT

Background: Isolated Hybrid Micro-Grid system is an interconnected system where numerous types of power plants like Micro-hydro, PV, Wind, Diesel etc. are connected with each other. In doing so, one isolated grid apart from national grid will be formed which helps to supply continuous power to certain locality where national grid is arduous to extend. For instance, if the power plant supplying power to an area 'X' gets failed due to several faults and if it acts as a part in establishment of isolated grid, in that scenario power in area 'X' will be supplied by other power plants which is the most important benefits in forming micro-grid.

Methods: As a college representative I took part with team of Alternative Energy Promotion Centre (AEPC) and Aspin Kemp & Associates (AKA)-one Canadian Company, to study micro hydro namely "Yafre Khola" and "Shobuwa Khola" in order to develop micro-grid in Taplejung. After scrutiny of different ways of generation of power from various renewable energy resources, individual simulation model of each system namely PV, WIND and MICRO-HYDRO was developed and finally they were interconnected with each other to form an isolated micro-grid.

Results: By tackling various obstacles, finally power in the overall simulation model of micro-grid system gets balanced i.e. the sum of power generated by various generating units equals the power consumed by the load and D-ELC (Discrete Electronic Load Controller). Rotor speed of various generating plants meets its frequency stability criteria. The output voltage waveform of the formed isolated grid was purely sinusoidal without any harmonics. The power output from wind and PV were varied using different input signal and in doing so too there exist power balance in the system. In order to note what will be the output waveform of rotor speed when certain amount of load is removed instantly at certain period of time, we detached certain load at 5 sec and it was noted that after certain time of fluctuation, rotor speed of various plants fulfilled its frequency stability criteria. To decrease the presence of harmonics Central D-ELC is used instead of ELC. Individual ELC of individual power plants were replaced by a single central D-ELC which lowers the cost of requirement of individual ELC. Finally we were able to develop control strategy for the Micro-grid having various types of generating units to give stable operation.

Conclusion: The parallel operation of two MHP plants with ACVC type ELC gives stable operation with proportional load sharing by ELCs. The parallel operation of two MHP plants –one with ACVC type ELC and other with D-ELC gives unstable operation. A Common D-ELC can give stable operation of Micro-grid with various types of Generators**.** In addition, on employing wind power plant, Photovoltaic along with Micro-hydro results in stable operation when central D-ELC is used.

INTRODUCTION

As name implies Micro-grid is a small version of national grid. Generally it is constructed in the rural areas where the demand of electricity is quite low. It means the total number of people and the equipment accessible to electricity is generally low. For instance Taplejung-one of the district of Nepal, the cost of transmission of national grid to this place is comparatively high and this district comprised of large number of micro-hydro plant within itself. So, by looking towards the benefits of Micro-grid it can be implemented in such areas such that the natural resources found within the place can be fully utilized and the people who want to get accessible to electricity fulfill their desire. The trend of development of the micro grid is growing up in Nepal. In Nepal, AEPC is promoting to develop Micro grid in rural areas. For the effective running of micro- grid, it must include different systems such as PV panels, Wind turbines, bio-mass, Micro-hydro and so on. All of these plants must work independently before they are interconnected with each other. In addition power generators are used as a backup supply, storage systems are also employed and moreover well-organized management system is necessary to ensure balance between supply and demand. Normally, in establishment of Micro-grid we require one Master power plant and the power plant having higher capacity is generally employed as master plant. Frequency and voltage of Master Power Plant is made stable anytime because all the other plants employed for developing micro-grid considers Master Plants frequency and voltage as a reference frequency and voltage. Micro-grid formation have several advantages too. Suppose a bucolic area having 20 houses and is located far away from the national grid. In such scenarios, it is quite unreliable to advance national grid to that place. If micro-grid is formed using the available resources within that areas then it will ensure reliability as well as reduce large amount of cost required for transmission of national grid. Micro grid systems facilitate remote applications and allow access to pollution-free energy. Since, formation of micro-grid helps to reduce the deficit of power in any locality as all the plants are interconnected with each other and ensure the supply of power in any case. Micro-grid promote the use of renewable sources of energy. Here we used two micro hydro, one PV and one wind renewable energy resources to form a micro-grid.

METHODS

Scrunity of the modeling of solar panel and dc/dc booster along with Perturbation and observation algorithm for maximum power tracking (MPPT) in solar panel and its applications were done. Additionally, inspection of modeling of Micro hydro with AC voltage controller and modeling of wind turbine were done using various sources. After that development of simulation model of individual units i.e.

1. Wind turbine connected to isolated grid with AC loads.
2. Isolated MHP with DLC.
3. Isolated PV system were done. After completion of all these simulation, development of simulation model of AC isolated micro-grid with above sources (PV, WIND, MICROHYDRO) using single controller i.e. Discrete Electronic Load Controller (DLC) was developed.

MODELS AND RESULTS DESCRIPTION

1.1 MATLAB SIMULATION OF ISOLATED HYBRID MICRO-GRID USING PV MICROHYDRO AND WIND:

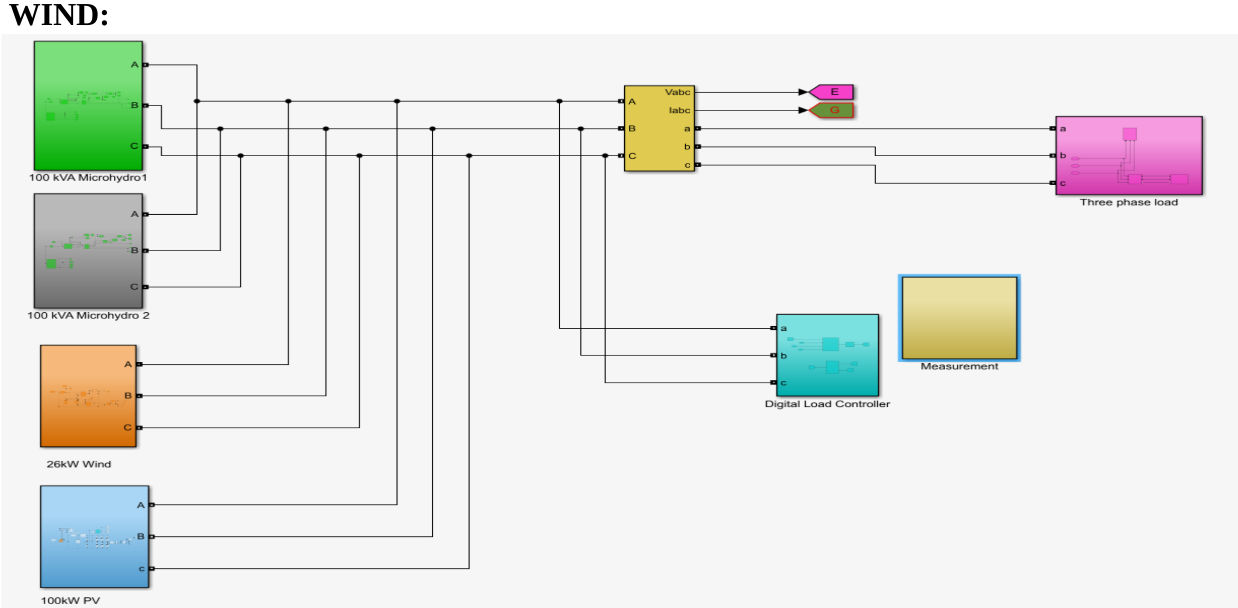


Figure 1.1 Overall system model

In this model a micro-hydro of two units having capacity of 100 kW each , photovoltaic having capacity 100kW and wind having capacity of 26 kW are interconnected with each other forming their own isolated micro-grid and a central D-ELC is used for control strategies. AC Load is coupled to the established isolated micro-grid. Discrete Electronic Load Controller (D-ELC) do not chopped any voltage across the dump load like ELC to increase or decrease the power consumed by dump load rather it turns on and off the discrete resistance. Here, P - controller is used to generate gate signals for required Numbers of TRIAC switch to be turn ON. In doing so harmonics arises due to waveform chopping in using Electronic Load controller (ELC) is highly reduced. Each of the simulation model is shown below:

1.2 SIMULATION OF GENERATION OF POWER USING MICROHYDRO PLANT

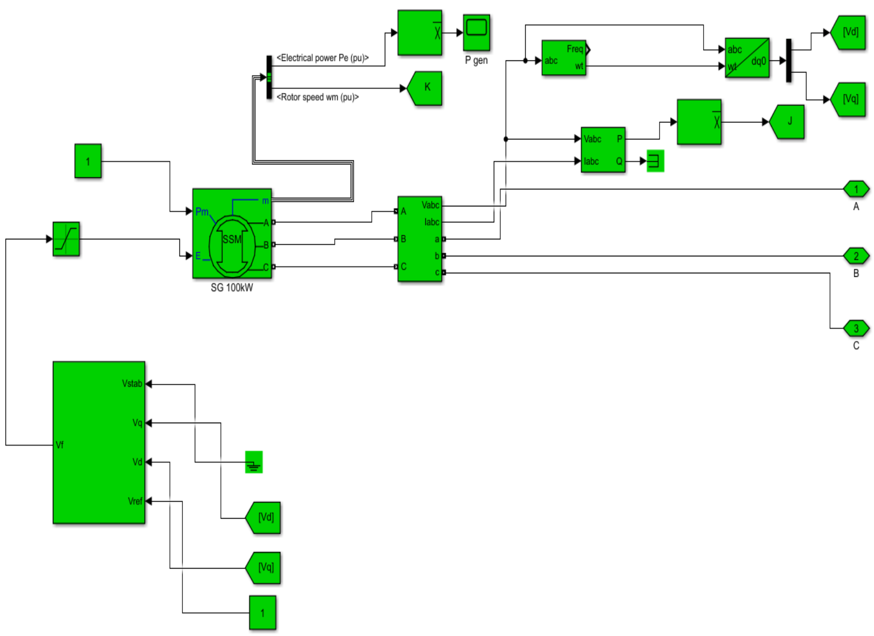


Figure 1.2 Simulation of Generation of power using micro-hydro plant

1.3 SIMULATION OF GENERATION OF POWER USING WIND ENERGY

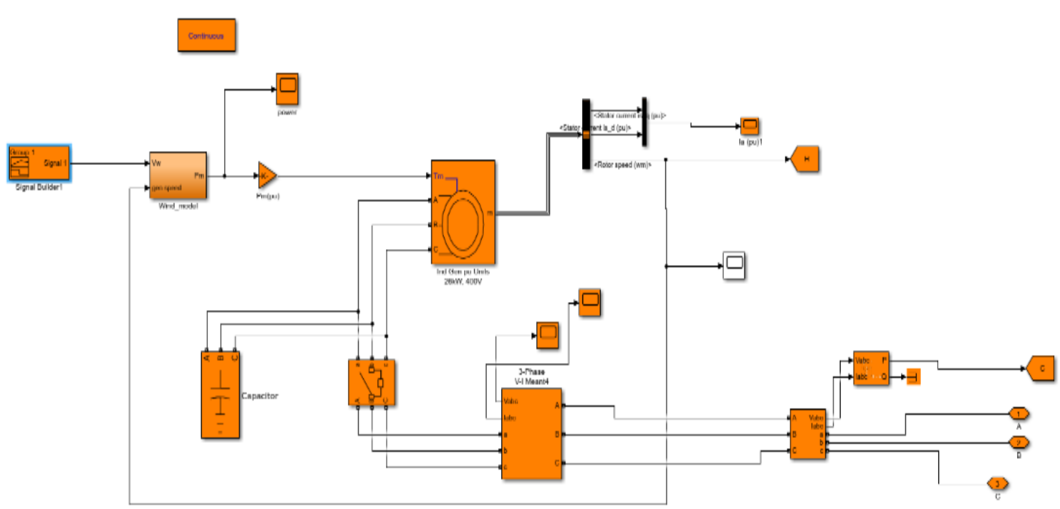


Figure 1.3 Simulation of Generation of power using wind energy

1.4 SIMULATION OF GENERATION OF POWER USING PV

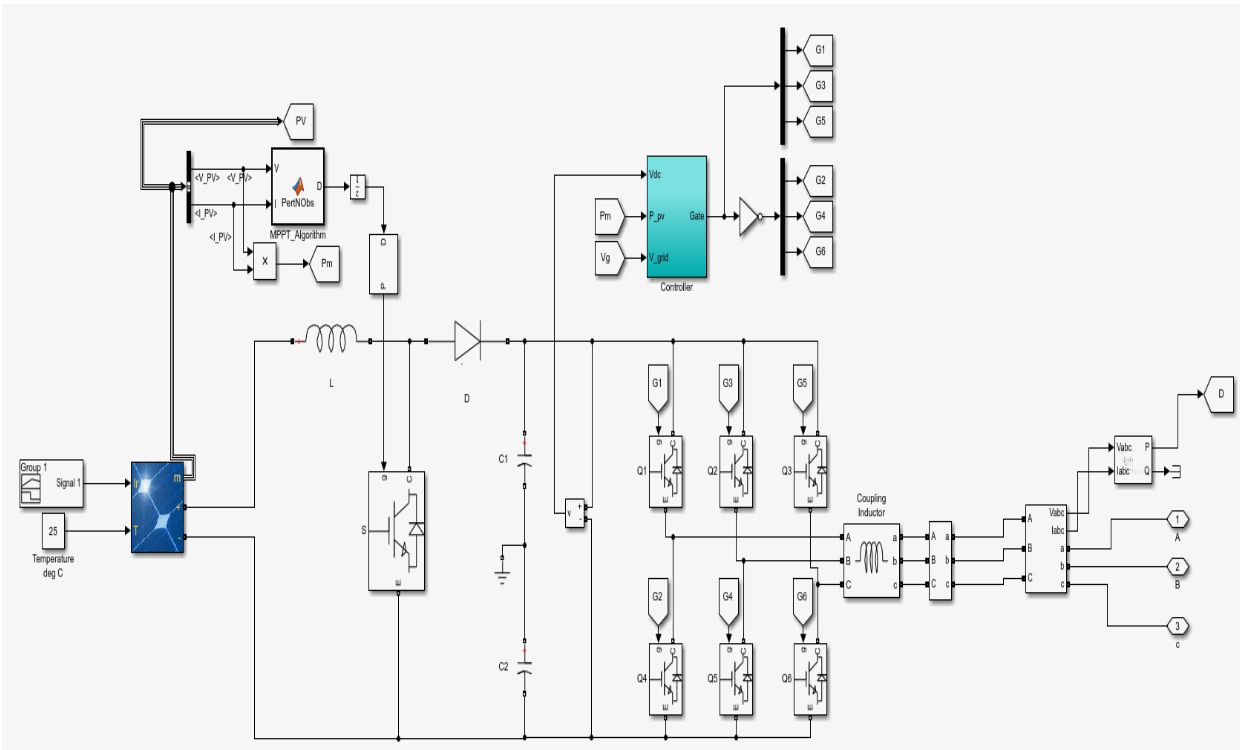


Figure 1.4 Simulation of Power generation using PV

1.5 DISCRETE LOAD CONTROLLER

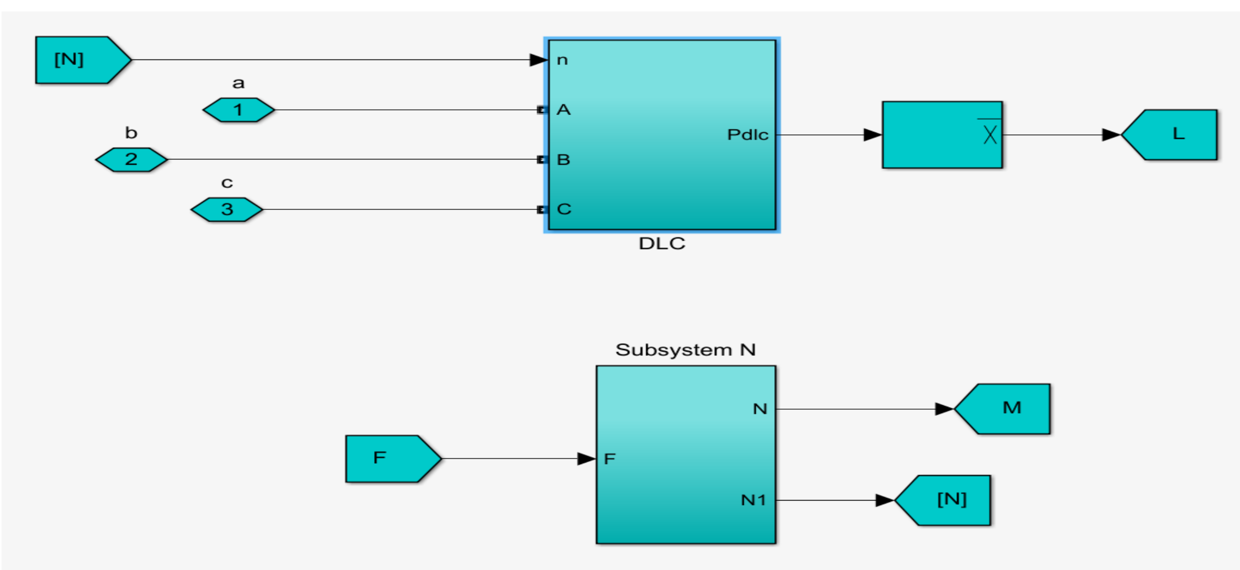


Figure 1.5 Discrete Load Controller

1.5.1 DLC SUBSYSTEM

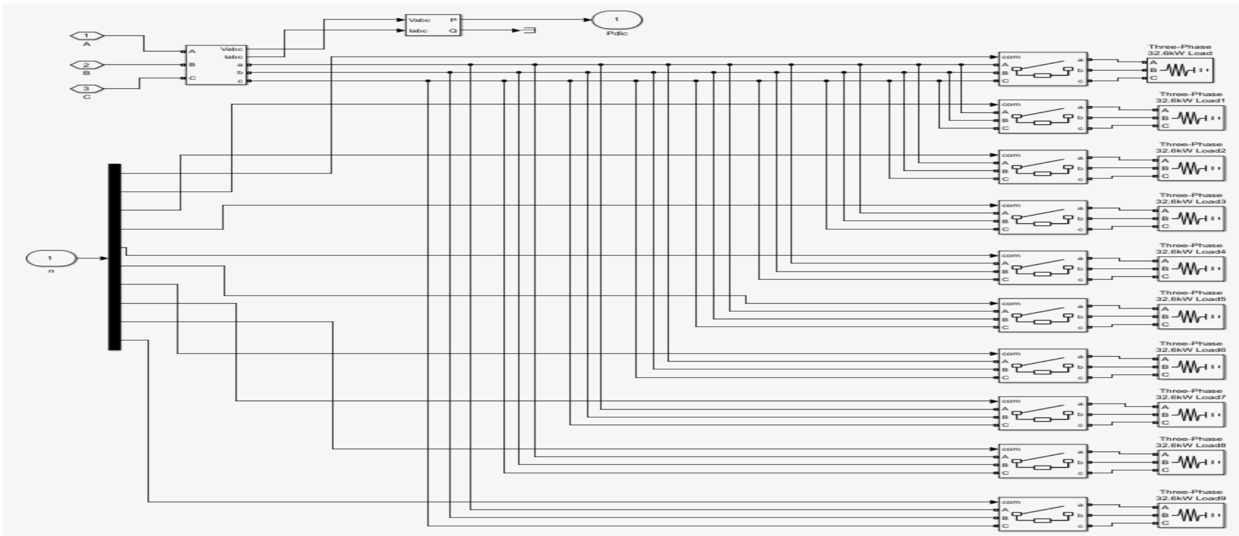
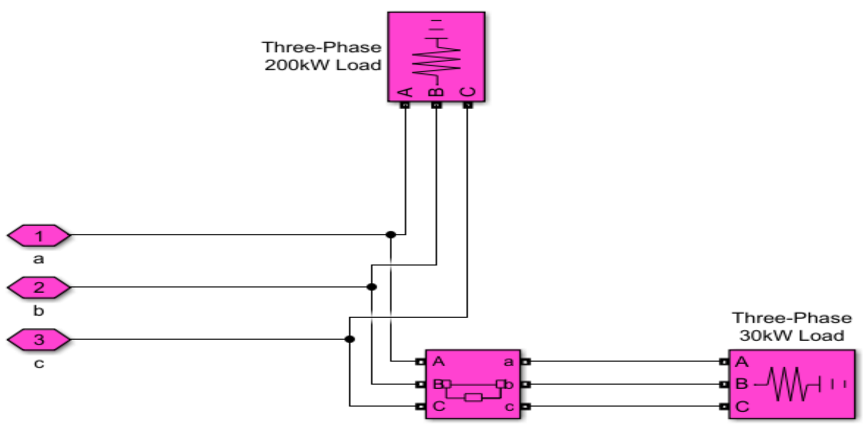


Figure 1.5.1 DLC subsystem

1.6 THREE PHASE LOAD



1.6 Three phase load

1.7 MATLAB SIMULATION RESULT

After generation of individual ac power from different sources they were interconnected with each other. But during interconnection various obstacles like power imbalance, output voltage waveform not being sinusoidal, in-stability of rotor speed, problem in conversion of dc power to ac power, requirement of long duration to run simulation occurs. By tackling all these issues, finally isolated micro-grid model was developed in MATLAB SIMULATION. The various outputs were noted and analyzed which are described below:

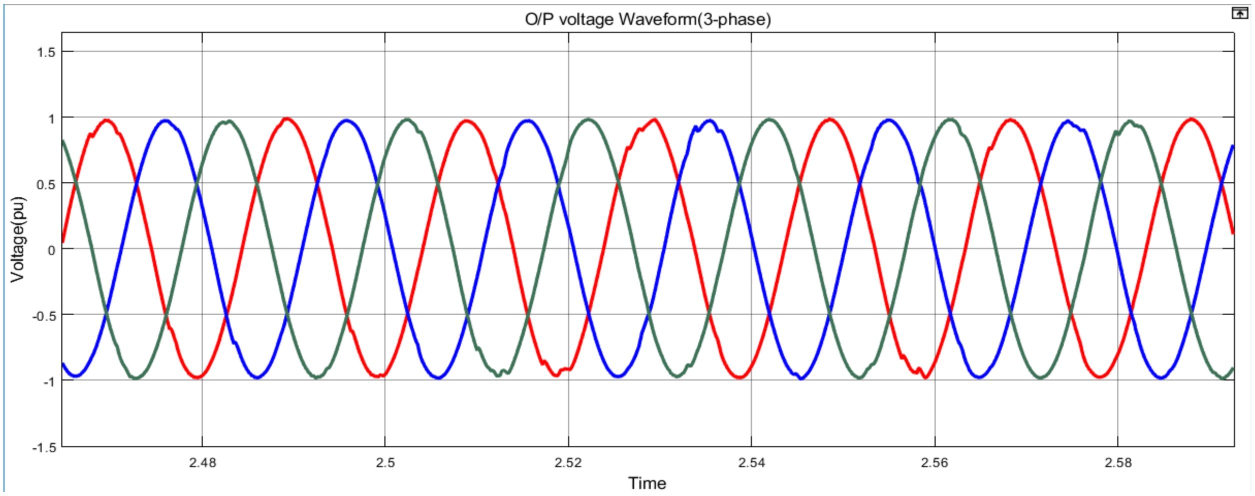


Figure 1.7 Plot of terminal voltage vs. time of the grid

After simulation of isolated micro grid the terminal voltage waveform of the grid was noted which is pure sinusoidal as indicated in the figure1.7.

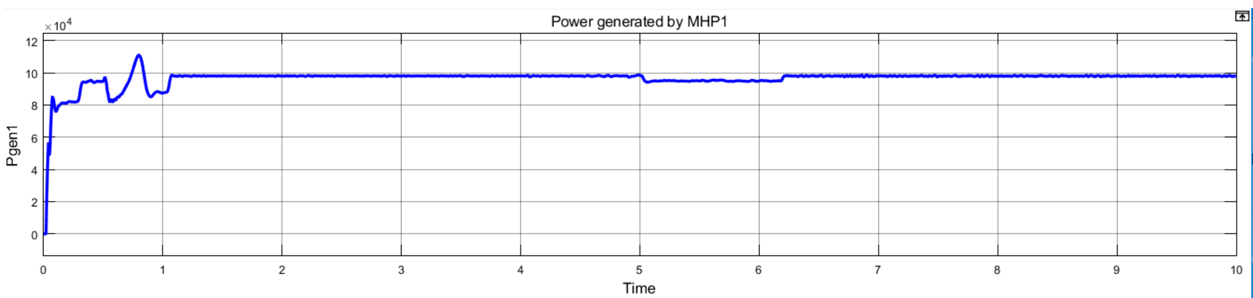


Figure 1.8 Plot of Pgen1 vs. time of MHP1

The figure is a plot of the active power generated in Watt versus time in second of Micro-Hydro Plant 1. The simulation was run for 10 sec. The period between 0 sec to 1 sec and 5 sec to 6 sec is considered as transient period. We used a generator of capacity 100kw and the output energy was nearly equal to 100kw which is denoted in the plot above. The transient in the period 5 to 6 sec arises because during this period certain load was turned off.

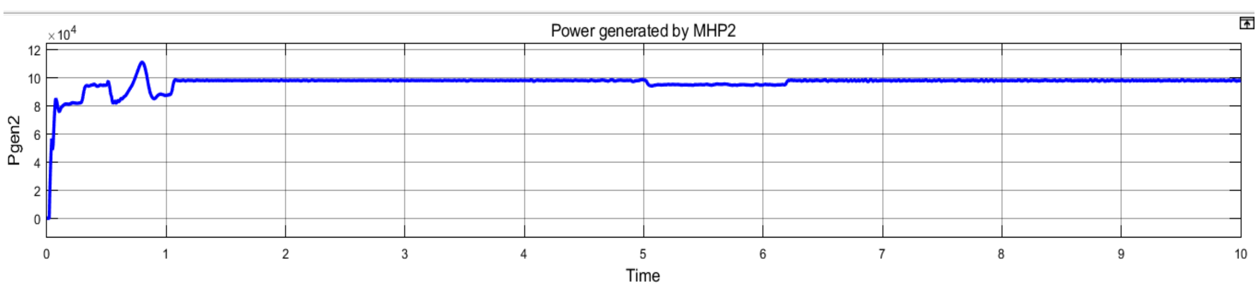


Figure 1.9 Plot of Pgen2 vs. time of MHP2

The figure is a plot of the active power generated in Watt versus time in second of Micro -Hydro Plant 2. Similarly the simulation was run for 10 sec. The period between 0 sec to 1 sec and 5 sec to 6 sec is considered as transient period and the output energy from the Micro-Hydro 2 is nearly equal to 100kw. The transient in the period 5 sec to 6 sec arises because during this period certain load was turned off.

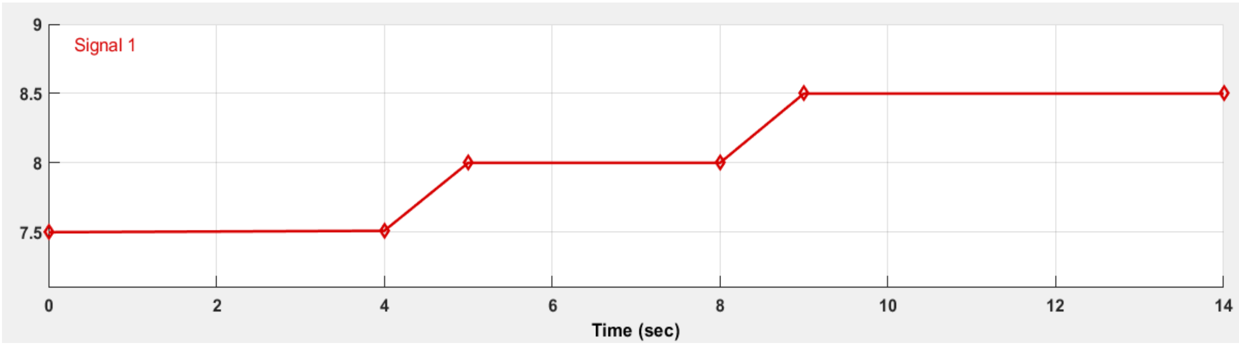


Figure 2.0 Plot of Varying velocity of wind

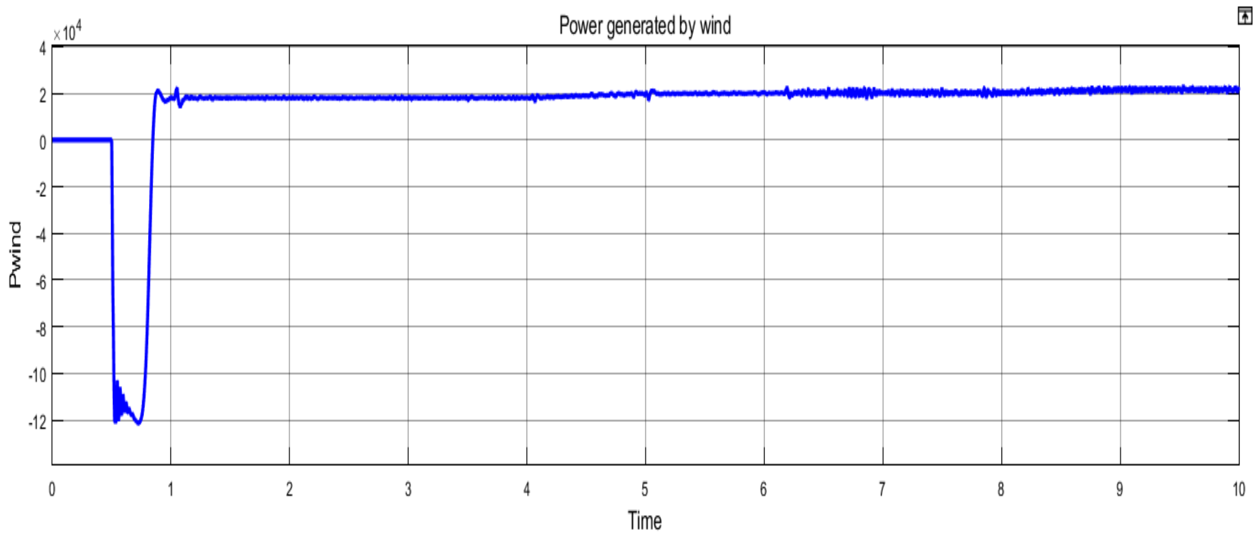


Figure 2.1 Plot of Pwind vs. time of Wind

Here the signal builder was used to vary the speed of the wind. Due to varying speed the emitted active power from the wind also get varied. Figure 2.0 represent the varying speed of the wind. Figure 2.1 is a plot of the energy generated from the wind in Watt vs. time in second. It was seen that during period 4 sec to 5 sec the speed of the wind increases and hence the transmitting power from wind also increased. Similarly during the period 5 to 8 second the speed remains constant and the power output also remained constant. During period 8 to 9 again speed of the wind increases and hence output stream from the wind also increased as indicated in the figure 2.1. The final transmitting power from the wind is about 22 kW in this project.

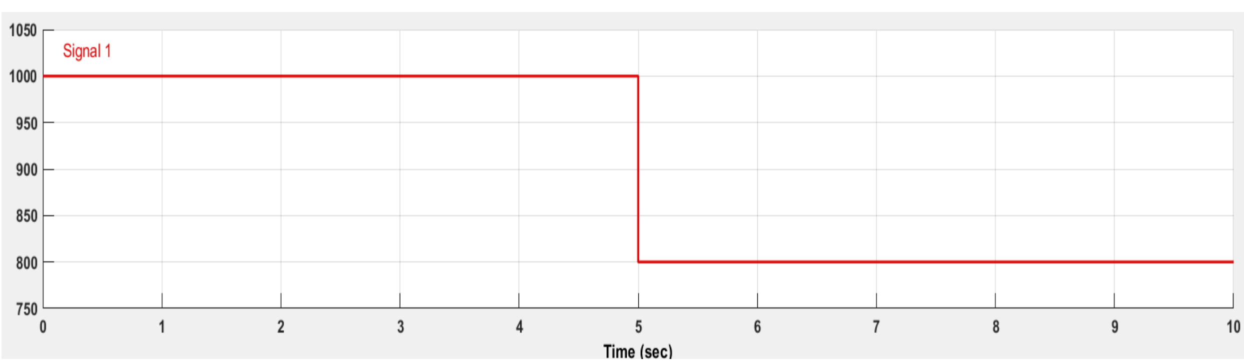


Figure 2.2 Plot of varying irradiance

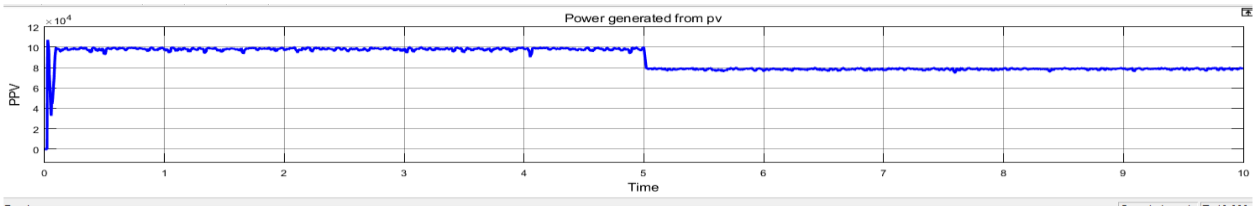


Figure 2.3 Plot of PPV vs. time

Figure 2.2 shows the plot of the changeable irradiance which is given through the signal builder. During period 0 to 5 sec the irradiance is 1000 and during period 5 to 10 sec the irradiance is dropped to 800. Figure 2.3 shows the plot of active power emitted from the PV vs. time in sec. Here over the period from 0 to 5 sec transmitting power is almost 100 kW and for the time from 5 to 10 sec the power output is nearly 80 kW. This result shows that the active transmitting power varies with respect to the irradiance in case of Photovoltaic.

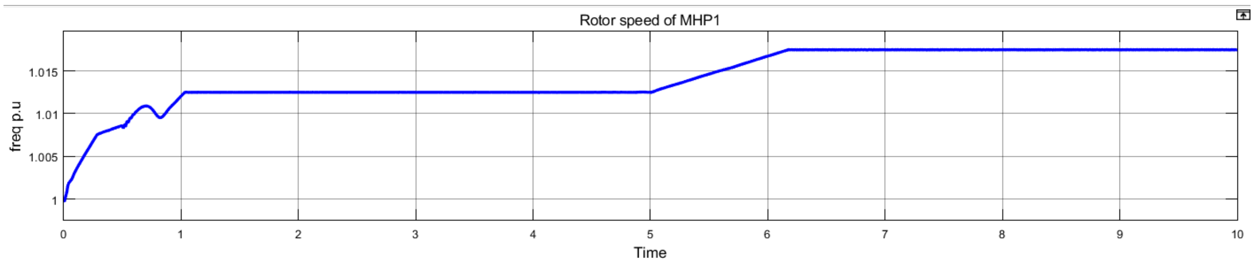


Figure 2.4 Plot of Enlarged view of rotor speed of MHP1

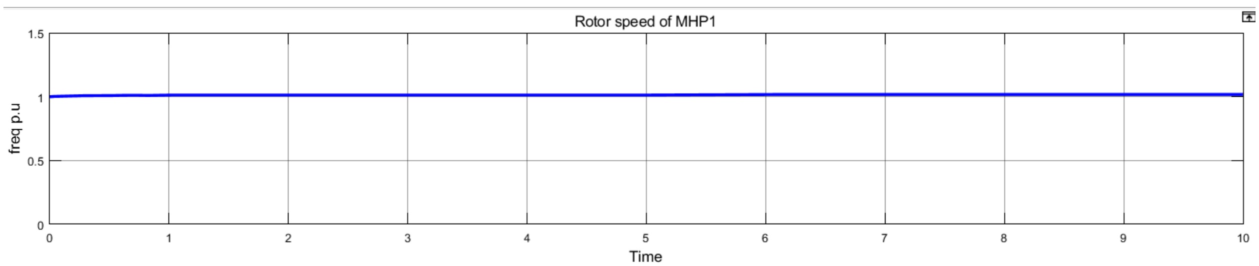


Figure 2.5 Plot of rotor speed of MHP1

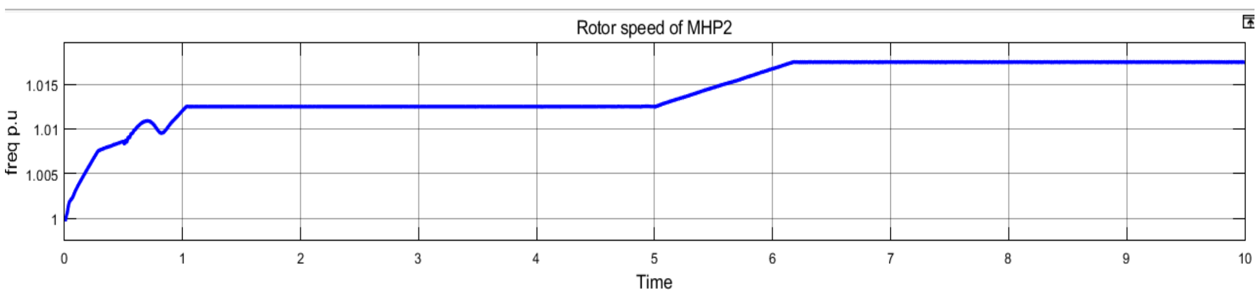


Figure 2.6 Plot of enlarged view of rotor speed of MHP2

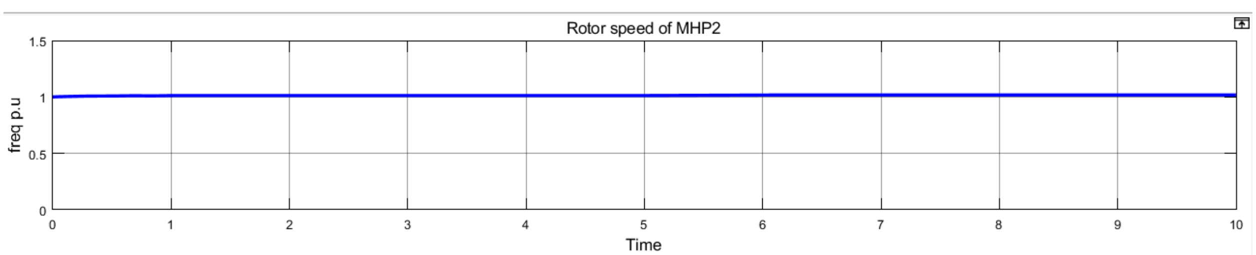


Figure 2.7 Plot of rotor speed of MHP2

A figure 2.4 shows the plot of enlarged view of the rotor speed of MHP1 vs. time. Figure 2.5 shows the plot of the rotor speed vs. time of micro hydro 1. Despite of anything whether the load is added or removed from the system the frequency remain almost 1 p.u .In the enlarged view during time period 5 sec load was removed and hence frequency increases but this increase in frequency is within the frequency stability criteria. After certain period of time the frequency remains constant at 1 p.u. meeting the frequency stability criteria. Similar phenomena occurs in case of micro hydro 2 which is shown in the figure 2.6 and figure 2.7.

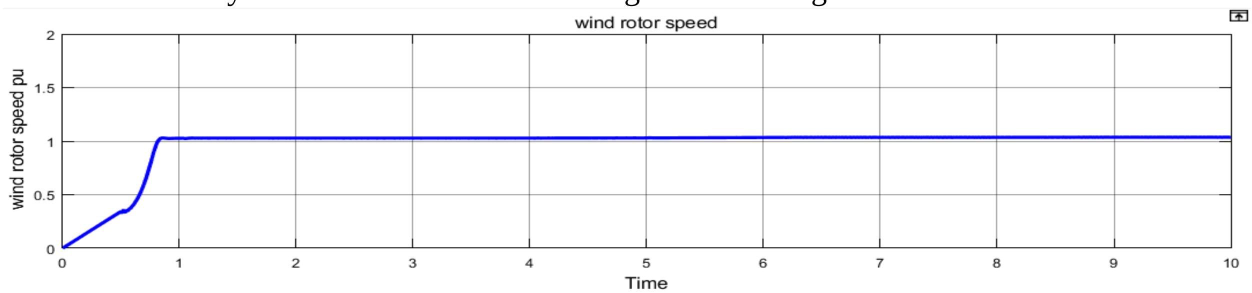


Figure 2.8 Plot of Wind Rotor Speed

Figure 2.8 shows the plot of the wind rotor speed vs. time. The frequency remains almost within 1 p.u in spite of whether load is added or removed from the system.

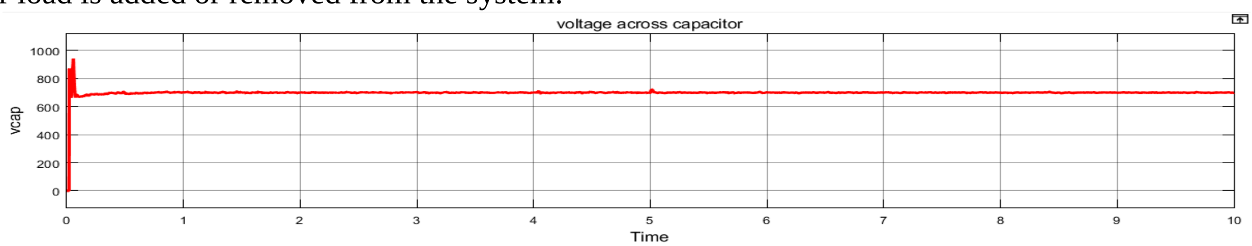


Figure 2.9 Plot of Voltage across Capacitor

Figure 2.9 shows the output dc voltage across the capacitor of fig 1.4. The dc voltage is maintained at a constant magnitude of 700 V. The voltage across the capacitor is maintained constant using the buck boost converter and furthermore maximum power point tracker (MPPT) phenomena was also considered to track maximum power. This capacitor acts as the source for the three phase inverter. After maintaining constant voltage at 700 V a logic is develop such that this dc voltage is converted into 3 phase ac voltage using the three phase inverter. During this period working of three phase inverter was clearly understood. Gate signal required for three phase inverter was developed using different strategies in separate model.

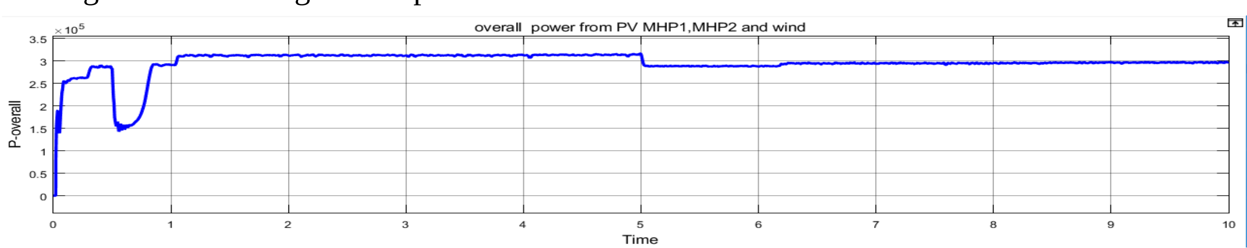


Figure 3.0 Plot of Overall Power from PV, Micro-Hydro and Wind vs. Time

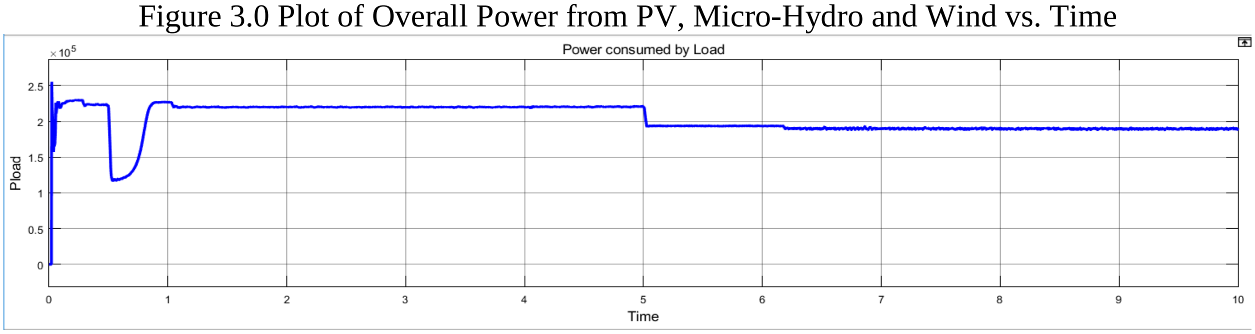


Figure 3.1 Plot of Power Used by load

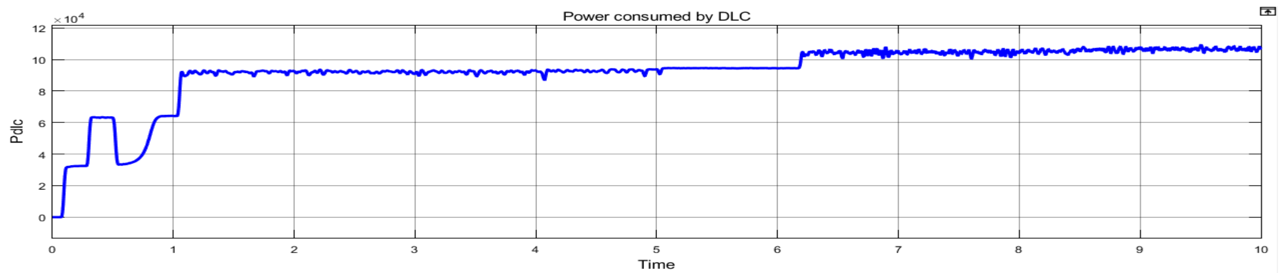


Figure 3.2 Plot of Power Deposited by DELC

The figure 3.0 is the plot of sum of total power emitted from PV, Wind, MHP1 and MHP2 vs. time. The figure 3.1 depicts the plot of total energy taken by the load. The figure 3.2 reveals the plot of total active power deposited by D-ELC. From the plot it is clearly seen that the total power generated equals the total power taken by the load + surplus power deposited by DELC.

ANALYSIS

It is viewed that the transmitting energy from two Micro-hydro Plant is 196 kW (98 kW from MHP1 AND 98 kW from MHP2). Similarly energy output from Wind energy varied from 18 Kw to 22Kw as the input signal of wind velocity gets varied according to fig. 2.0. And the power output from PV also gets varied from 97.9 kW to 78.5 kW due to fluctuated irradiance given from the signal builder as indicated by signal in fig. 2.2. The total electricity required by load also gets altered from 220kW to 189 kW because certain amount of load was turned off after 5 sec. The total energy deposited by D-ELC also fluctuated from 92 kW to 105Kw at end, it is because certain load is outraced after 5 sec and since all of the generating units generate constant amount of power and the surplus power has to be deposited by the ballast load (D-ELC). So, the power deposited across ballast load get increased due to decrease in load for power balance in the system. For instance, taking the period of 0 to 5 sec, the total power produced from all the generating plant is about 312 kW and the power consumed by load is 220 kW and power deposited to D-ELC is 92 kW. It means power generated equals power consumed. Hence, there exist power balance in the simulation model of project. Similarly, talking about the end of period the total power generated is equal to 297 kW. Electricity consumption by load is 189 kW and surplus power deposited by D-ELC is 108 kW. It means there exist power balance throughout the period. So, as a result this simulation project is able to form stable isolated micro-grid.

CONCLUSION

With the implementation of this simulation project it is viable to diminish the transmission line cost required for rural areas which are situated far away from the National Grid. Similarly we can use a central D-ELC for control strategy which help to reduce the cost of individual D-ELC required for each power plant. Moreover, by following the same strategies numerous types of other power plants like nuclear plant, diesel plant, bio-mass etc. may be interconnected with each other to construct micro-grid in the near future.

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