DESIGN A CLUSTER BASED SMART MICRO-GRID CONTROL ALGORITHM VIA HVDC LINE

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ABSTRACT: Electrical energy is one of the most important commodities in today's world. It is important to match electricity supply with demand to provide a reliable power supply because of unpredictable increase in electricity consumption. Instead of building a large power supply system anda HVAC transmission line, a smart micro-grid and a HVDC transmission line can be seen as a promising option for remote installations. This research was to design a cluster based smart microgrid and develop a control algorithm to transfer power between two microgrids via HVDC line. These microgrids can operate in both grid-connected mode and off-grid connected mode. Rather than using a conventional HVAC transmission line, a HVDC line was used to enable power transmission between microgrids. The entire microgrid system is simulated in the MATLAB Simulink platform and the results are analyzed. The simulation model of the microgrid includes the Solar panel, Micro Hydro, Battery Bank, critical loads and non-critical loads. The performance of the system is analyzed under the two different transient conditions and the simulation results are verified.

Keywords: Micro Grid, HVDC, HVAC, MATLAB, transient condition

1. INTRODUCTION

Electrical energy production for utilization comprises complex systems in the three phases; electricity generation, transmission and distribution to consumers. It is challengingto guarantee a reliable power gird with minimum interruptions due to mismatch between demand and supply. The National Grid in Sri Lanka has a drawback. When a failure occurs in the utility grid there is a countrywide blackout. This problem can be addressed by designing cluster based smart microgrids (MGs) with HVDC transmission lines to transfer electrical energy between microgrids.

MG is a newly developed concept in power system architecture that comprises electricity generation sources and small loads [1]. When power interruptions occur in the utility grid, MGscan operate in self-sustained mode with intelligent control over the entire microgrid. MG offersmany advantages such as better power quality, resiliency, reliability and being more economical and more environment friendly.

HVDC transmission does not have a stability problem because it does not have limitations for frequency components and it is not limited by transmission distance. So, it can transmit power over long distances. In general, HVDC transmission lines impacts less on the environment and therefore, HVDC transmission lines have better performance than HVAC transmission lines [2].

1.1 Problem Formation

Reliability and resilience are more important for sustainable power delivery. This issue can be managed by implementing AC MGs with HVDC transmission line to transfer electrical power between micro grids. As the utility grid and most loads use AC, the AC micro grid can easily integrate with the national grid.

2. METHODOLOGY

MATLAB 2019a Software was used to simulate the entire micro grid system. The overall structure of the system is shown in figure 1. It consists of 230-V, 50-Hz, single phase two AC microgrids and HVDC line to transfer energy between them. Each MG comprises a PV array, Battery Bank, Inverter, Micro hydro, critical loads and non-critical loads.

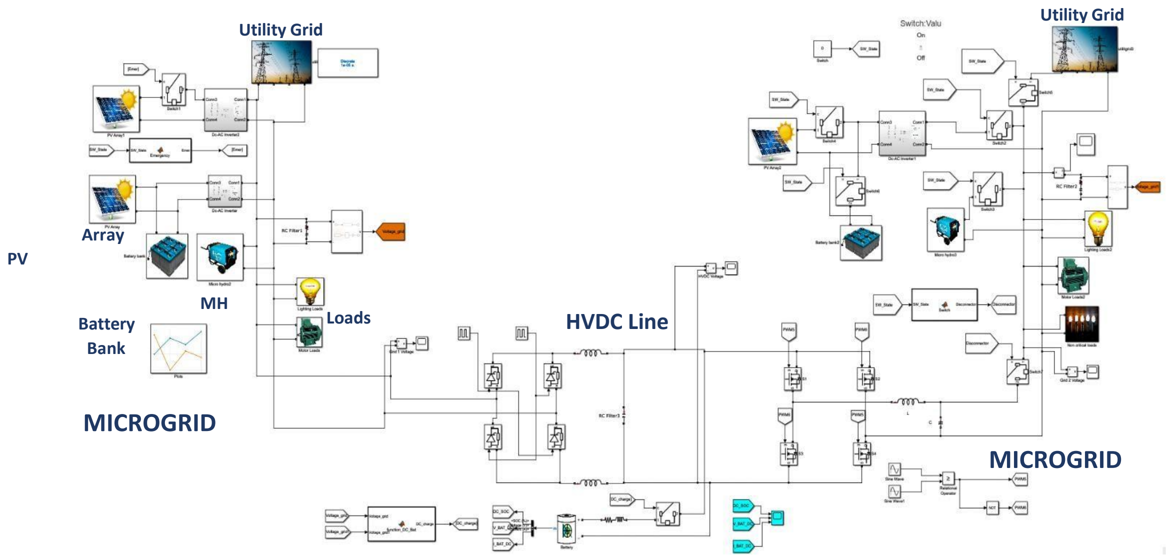


Figure 1:Structure of complete MATLAB Simulation system

2.1 PV Array

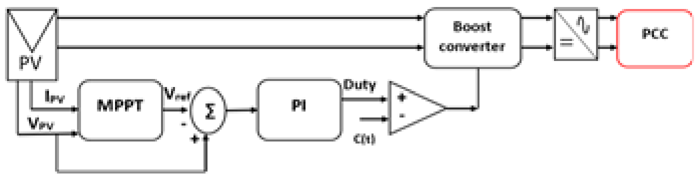


Figure 2: MPPT Close loop control diagram

A PV array is one of the renewable energy sources which is connected to the microgrid using a micro inverter. Due to photovoltaic action, DC power is generated. This power is given to MPPT (maximum power point track) which transfers maximum efficient power to the DC-DC boost converter.

2.2 DC – AC Inverter

A single-phase inverter is used to connect PV array to the single-phase AC grid which converts DC into a form of AC. Power generated by the PV array is not stable all the time. This inverter helps in ensuring grid stability by the integration of the PV power output.

2.3 Micro-hydro

A three phase asynchronous machine is used to model the micro-hydro. The C2C method is used to convert it into a single phase. In this method proper rotating direction of the rotor should be ensured. Unbalanced arrangement of capacitance helps to compensate for the unbalanced load on the generator and the derating factor when the unbalanced motor operation is 80% of the motor the rating.

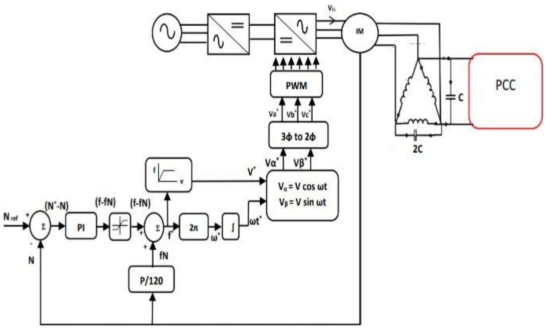
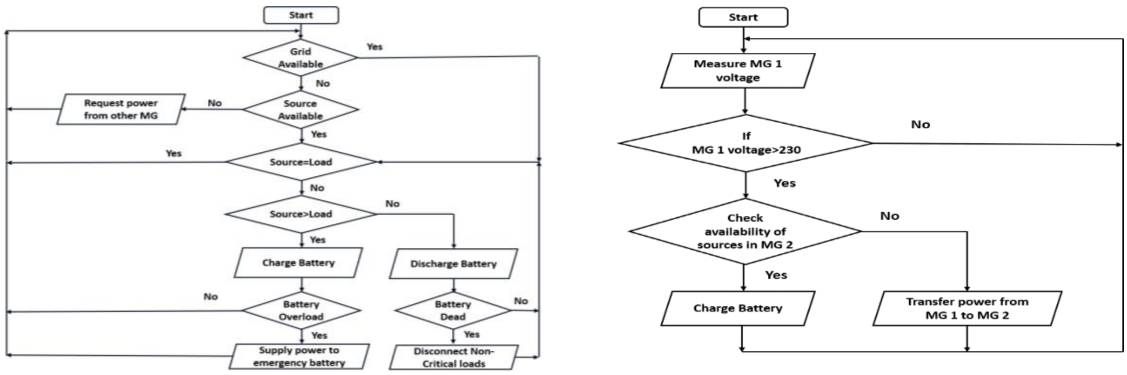


Figure 3: V/F control of Micro-hydro

2.4 HVDC transmission system

Mainly, an HVDC transmission system can be divided into three parts; 1) First converter station to convert AC to DC. 2) Transmission line. 3) Second converter station to convert DC to AC. An extra battery is connected to the HVDC line. When the grid voltage is higher than 230-V the battery will charge by using excess power.

2.5 Control algorithm



(a) (b)

Figure 4: Control Algorithm for Microgrid (a) and HVDC line (b)

3. RESULTS AND DISCUSSION

Two case studies are verified through this project and the stability of the voltage and the frequency of the proposed system are examined.

Case A: When power interruption occurs at the Utility grid

This means island mode of the MG. At this time energy is generated by micro sources. The microgrid voltage variation is illustrated in figure 5. The voltage of the system illustrated in the graph is stable after 0.3 seconds and it is nearly equal to the 230-V.

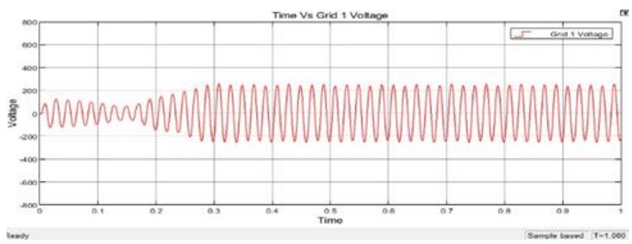
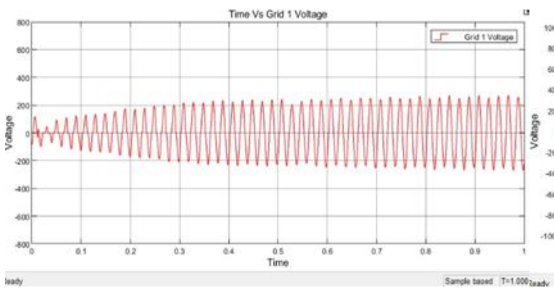


Figure 5: Microgrid voltage

Case B: Transient at the Utility grid and energy sources

In this case an assumption has been made as a transient occurs in MG 2. During this condition, the excess power in MG 1 is supplied to loads of MG 2. The entire system performance is simulated for the duration of 1 second. First 50% is simulated with transient and the rest of the part is simulated without transient. The microgrid 1 voltage is illustrated in figure 6 and microgrid voltage 2 is illustrated in figure 7. It can be observed that in both graphs, the system voltage is stable and almost equal to 230-V.



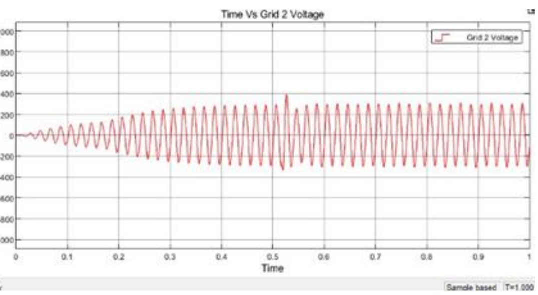


Figure 6: Voltage of Microgrid 1 *Figure 7: Voltage of Microgrid 2*

In this case, MG 1 supplies power to MG 2 via HVDC line. The HVDC line voltage is illustrated in figure 8.

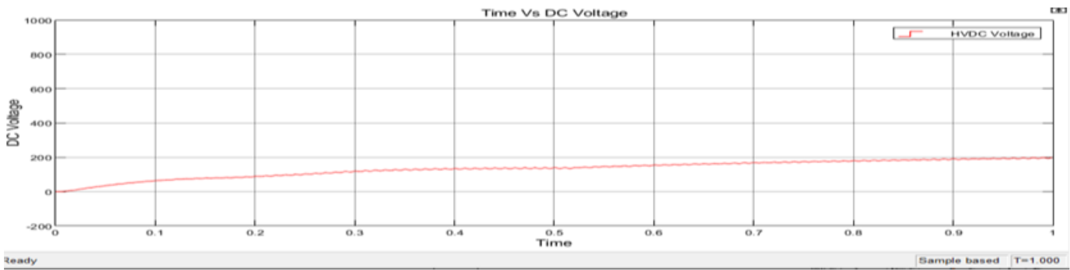


Figure 8: HVDC line voltage

4. CONCLUSION

This project mainly focused on designing a cluster based smart micro grid and developing a control system for transferring power between two micro grids via an HVDC line. The specialty of the project is that this microgrid can operate in both grid-connected mode and off grid connected modes. The whole system is controlled in autonomous mode according to the given inputs. This MATLAB model has been tested under two transient conditions called "transient at the utility grid" and "transient at utility grid and energy sources". Eventually, the proposed microgrid system can be operated in both cases.

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