Solution for interconnecting power plants in the Eluvaitivu Island Hybrid system

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1.Introduction

Present expectation of the world, refer to the electrical power generation is mainly concern about the environmental pollutions. But the usage of renewable energy (RE) resources are alternative solutions to avoid environmental issues. The renewable energy based generation capacity in Sri Lanka includes major hydro, mini hydro, solar, wind, and biomass technologies. However, the RE power plants do not have the capability of providing firm power because of the intermittence nature of its source such as solar irradiance and wind pattern. Therefore, the RE resources such as solar and wind are commonly considered as non dispatchable power plants. One of the methods to mitigate this issue is by the combination of RE with diesel generators and/or battery storage systems (BSS).

This application was implemented in Eluvaitivu which is an island located in the northern part of Sri Lanka and inaugurated in February 2017. This project consists of a 30 kVA diesel generator, six number of wind turbines each 3.5 kW, total capacity of 46.28 kWp solar panels and total capacity of 134.86 kWh, 20 numbers Lithium ion batteries are contained in this project. Other than this, a 100 kVA diesel generator separately used to supply power to the island during night time. The connection diagram of 400V distributed energy system in Eluvaitivu shown in Figure 1.

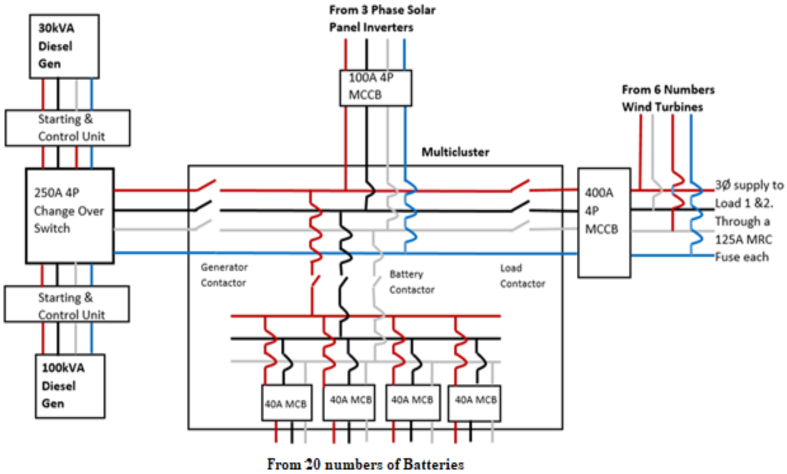

Figure 1: Interconnection of solar, wind and diesel plants, batteries and loads through multicluster

Here the solar power, diesel generator and battery are connected to the main 400 V bus bar through contactors in the multicluster. The operation of the contactors are controlled by the logic circuits. This 400 V bus bar is connected to the loads through a 400 A, 4P MCCB. On the other hand three phase supply from 6 number of wind turbines are directly connected to the load bus outside the multicluster. If any wind turbine is under repair, this may cause unbalance in generation.

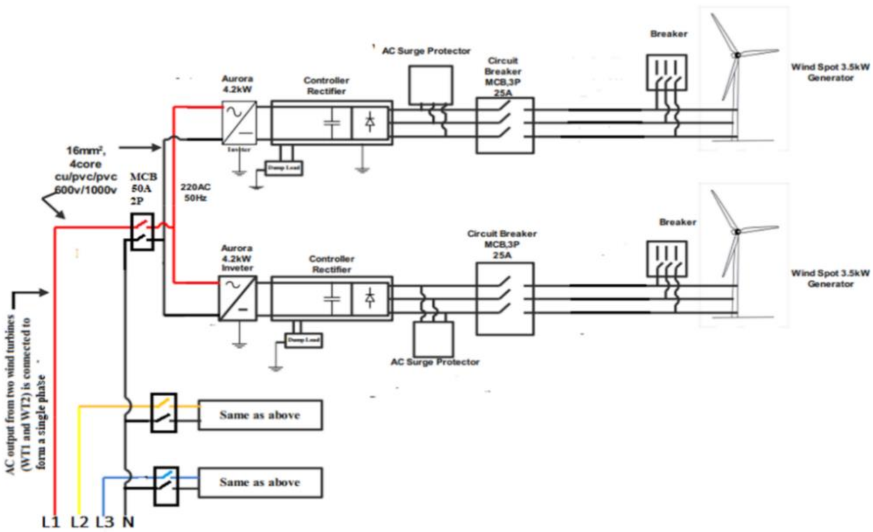

Figure 2: Connection of individual wind turbines through rectifier and DC/AC inverters to form three phase supply.

The connection diagram of 6 numbers of wind turbine is clearly shown in Figure 2 and Figure 1. Here a single phase AC output obtained from 2 wind turbines. Similarly, 3 Single phase AC outputs obtained from all 6 number of wind turbines. However, these three single phase AC outputs are not having 120 degree phase shift or equal magnitudes. In other words, RE power plants side is not creating three phase balance voltages. But on the other hand, diesel power plants create three phase balance voltages. Therefore, as it is, it will have heavy risk one connecting unbalanced systems together. It is because, the both side voltages will have extreme difficulties on satisfying synchronization requirements (especially on keeping 120^{o} phase shift and equal magnitude of three phase voltages from the wind power systems). This is one of the issues that makes difficulties in interconnecting RE power plants together with diesel power plant, when wind power plant is in operations.

This issue could be resolved by replacing all six single-phase inverters with one 3-phase inverter, to connect wind power plants together with main three phase system. This will simplify the synchronization process because one three phase inverter already produce balance three phase voltages.

2.Methodology

(i) From all 6 wind turbines a common DC interconnection busbar to be made after the rectifiers, (ii) From the DC interconnection busbar, a three-phase DC to AC inverter have to be placed to produce three phase balanced AC voltages and (iii) This three-phase AC balance voltages, from inverter, can be connected easily with three-phase AC output voltages from the diesel power plants using usual synchronization method. Accordingly, the interconnection circuit diagram is shown in Figure 3 as a proposed solution to minimize the risk on the synchronization.

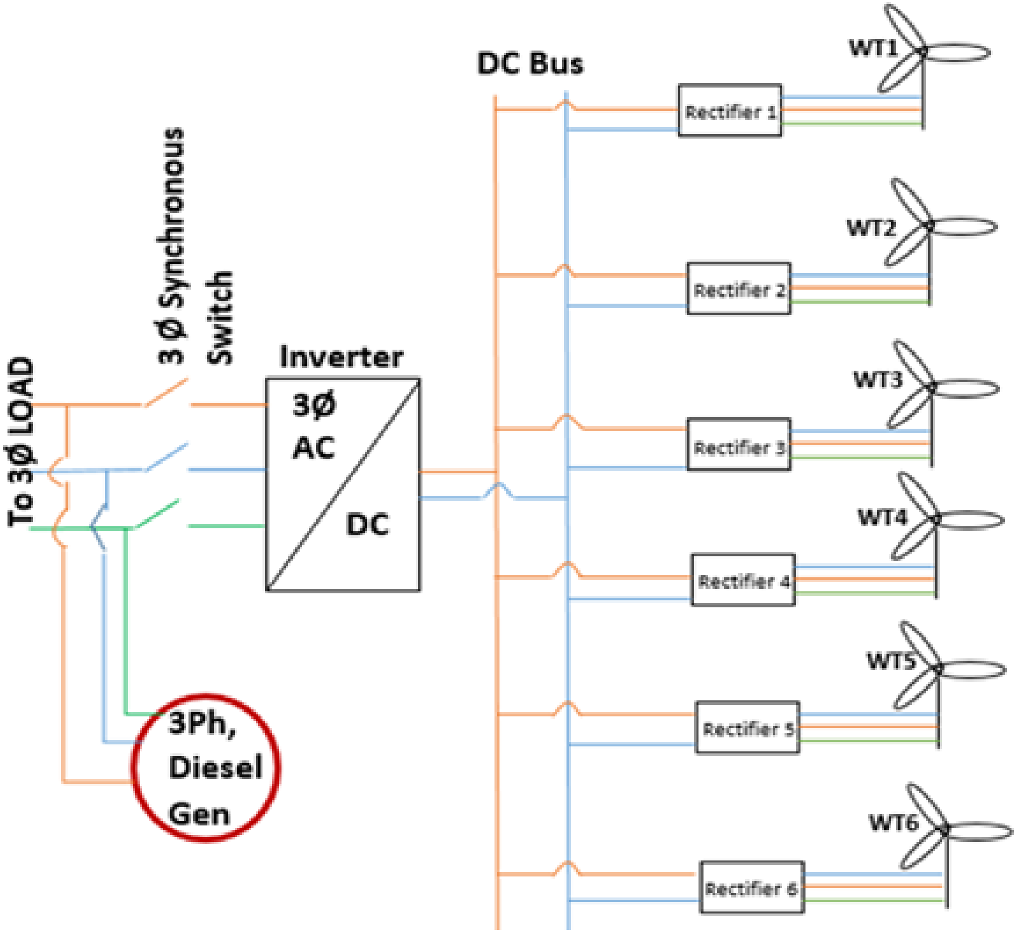

Figure 3: Proposed connection diagram of 6 numbers of Wind turbine

3.Brief of control circuits with the proposed system

3.1 Battery with inverter circuits

Fixed frequency of 50 Hz and 400 volt line to line was used to produce three phase voltages at the common connection point. Accordingly, this will operate as slack bus in this system. Further the State of Charge (SOC) of the battery was used to control the diesel generator requirements. Therefore, the control concept of the battery system should be carefully designed whenever different generators are connected.

3.2 Wind turbines with inverter circuits

All six wind turbines output were rectified and connected to a DC bus as already mentioned. Then one three-phase DC to AC inverter is used to connect the wind systems to the common connection point. Here the active power control of the inverter is done by regulating the DC bus voltage to its rated value. This make sure all the active power received from the wind turbines is supplied to the grid. The reactive power control of the inverter is done by maintaining the unity power factor at its AC output. This is achieved by controlling its internal AC voltage magnitude. Here the common connection point grid voltage's phase angle is taken for the purpose of synchronization, using a Phase Lock Loop (PLL).

3.3 Solar panels with inverter circuits

All solar panels output were connected to a DC bus. Then three-phase DC to AC inverters are used to connect the solar systems to the common connection point. Here the active power control of the inverter is generally controlled by Maximum Power Point Tracking (MPPT) control which is done by regulating the DC bus voltage at its selected value.

When batteries are fully charged it was observed that these inverters reduce the power taken from solar panels. This can be named as operating in power blocking mode. This minimizes the requirement of the dump loads.

The reactive power control of the inverter is done by maintaining the unity power factor at its AC output. This is achieved by controlling its internal AC voltage magnitude. Here, the common connection point grid voltage's phase angle is taken, for the purpose of synchronization, using a PLL.

3.4 30 kVA Diesel generator control concept

The diesel generator operation is controlled based on the SOC of the Battery Energy Storage System (BESS). Whenever the SOC reduces below its set threshold (according to its operating criteria), the diesel generator is triggered to be switched on. Accordingly, the diesel generator synchronized its terminal voltage and connected to the main grid. When battery's SOC is recovered, diesel generator is switched off.

3.5 Dump load control

The dump load is controlled based on the battery's SOC level. Whenever the SOC increases above its set threshold, the dump load is triggered to be switched on as the last option. Accordingly, the dump load helps to discharge the excess energy in the battery.

3.6 100 kVA Diesel generator control concept

The 100 kVA diesel generator was connected as separate generator to supply loads during the night time when the battery's SOC goes below its lowest threshold. Here it is operated as slack bus.

If this generator needs to be synchronized with the RE hybrid system, its slack bus control concept has to be carefully designed together with the battery's slack bus control concept (An interconnected system can have only one slack bus).

4 Results

Figure 4 shows that the wind turbine three single phase voltages. Here there is no guaranty that 120-degree phase shift is given among the three phase voltages. Figure 5 shows wind turbine three phase voltages with equal 120 degree phase shift. This guaranteed that the three phase voltages are 120 degree phase shifted and maintained balance supply voltage conditions. Therefore, it is easy to synchronize with the common connection point.

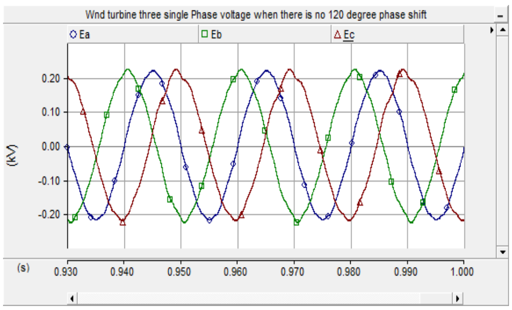

Figure 4

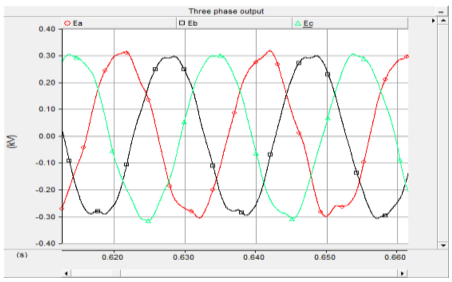

Figure 5

5 Conclusion

The Eluvaitivu hybrid system will be the ideal small interconnected grid with many resources to analyze comprehensively on stability improvement, power quality improvement and reliability improvements. The similar concept could help to expand the electrifications of other islands and any isolated and remote villages. This is an excellent example, which proves that the research and development will always find solutions to the real world problems.

This study has proposed a solution for interconnected operations of wind, solar, battery energy storage together with 100 kVA diesel generator. When the battery energy storage's state of charge become less, the diesel power plant is energized to support the generations. Further analysis on this is being carried out for optimized operations of the energy resources.

6. Acknowledgement:

We sincerely thanking the Former Deputy General Manager, Northern Province Eng. Priyantha Gunathilake and DGM of Northern Province Eng.S. Prabaharan, Chief Engineer Eng. Lingaruban and his team members Mr.Kirushanthan, Mr.Karthik and Mr.Ramanitharan.
We also thank the Faculty of Graduate studies and Faculty of Engineering of the University of Jaffna for their continuous support and encouragement.**7. References**

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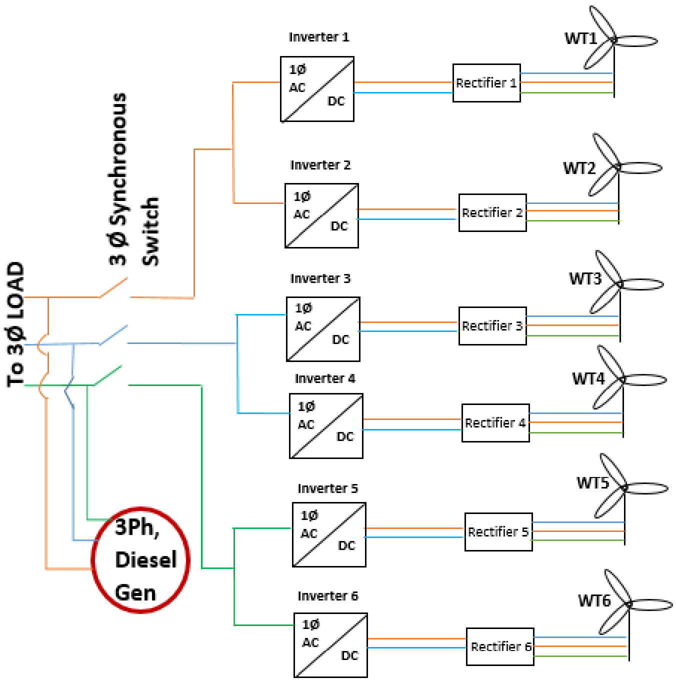

Figure (i): Existing connection diagram of 6 numbers of Wind turbine

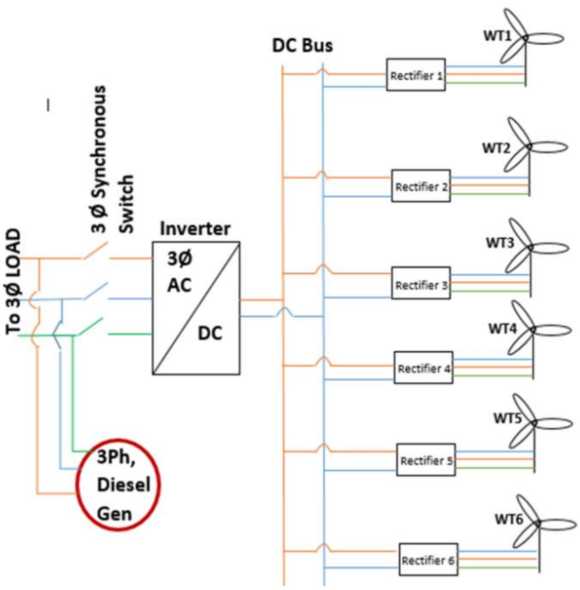

Figure (ii): Proposed connection diagram of 6 numbers of Wind turbine