**Test No: 1.0 – HOMER Simulation**

Hybrid Optimisation Model for Electric Renewables (HOMER) is a software package that allows users to model on-grid systems, off-grid systems or hybrid systems. HOMER allows users to add multiple AC or DC (or both) loads specifying the power demand profile of the load including peak consumption and life times. Once the load has been specified the user is able to add various other technologies such as; renewable technologies, storage technologies, generators, converters and the grid. These technologies act as variables in the optimisation process and when the technologies have been chosen the user may input various values for HOMER to use in the simulation. For example, if PV was added to the simulation the user may specify a 100 kW, 150 kW and 200 kW PV array and then HOMER would use each value in turn in the calculation towards the optimal solution.

The optimisation procedure HOMER undertakes, involves calculating various parameters such as net present cost (NPC), operational costs, initial capital costs, renewable fraction and energy production per technology for all possible combinations of systems. Not all system combinations, however, will be viable based on the specified load requirements. From the viable solutions, HOMER lists the system combinations in order of NPC outlining the best system as the one with the lowest NPC. The disadvantages of the HOMER simulations are that voltage and current (v-i) relationships are unknown also the user has no control over how each technology is operated throughout the lifetime of the project.

**Test Specifications**

The main requirements that will be traced during this test are requirements (1), (2), (5), (8), (9). As mentioned above the load characteristics will be entered into the simulation, this includes the total power the load will need, the power demand profile of the load, project life time, and location of the load. When the HOMER software preforms the calculations on all the different combinations of the system it removes combinations that are unfeasible. These unfeasible combinations are ones that do not meet the characteristics of the load by either being unable to supply enough power to the load or unable to power the load for the desired profile. Therefore, all the feasible system combinations that HOMER outputs are capable of powering the load for the desired time, hence meeting requirements (1), (2) and (8). A renewable fraction is also given for every feasible system combination and therefore the systems can be tested against how environmentally friendly they are and therefore how well they meet requirement (9). As mentioned above the HOMER software ranks the feasible system combinations in order of increasing NPC. This allows the user to determine which system is the most economic and for Team Power, allows them to compare different systems and how well they meet requirement (5).

**Test Description**

Firstly, values for parameters of the load must be entered into HOMER. A blank power profile will be chosen for the load and 95 kW will be entered for every hour of the day resulting in an energy demand of 2,280 kWhr per day. The life time of the project will be set to 10 years. The location of the borefields will be entered into the location search screen and the solar insolation and temperature data for Newman will be downloaded. An auto size diesel genset will be selected. The generic flat plate solar cells will be chosen to represent the PV and array sizes of 100 kW to 200 kW in increments of 10 kW will be entered into the ‘search space. Lithium ion batteries will be chosen for the storage system setting total batteries of 100 – 500 in increments of 50 will be entered into the ‘search space’. A converter will be added to allow DC to AC conversion. The simulation will then be run and the feasible combinations will be listed in order of increasing NPC.

**Test Result Analysis**

After running the simulations HOMER listed the four feasible system combinations (Figure 1). One of the system consist of a warning sign which indicates that there are instabilities in the system that could cause problems even though the system meets the requirements of the load. From Figure 1 it can be seen that combination 3 and 4 consist of only a generator and a generator and battery combination, respectively. These two options along with the second option which indicates a warning have been disregarded. Therefore, the first solution is the only feasible hybrid solution from this test which is also the most economically viable solution as it has the lowest NPV.

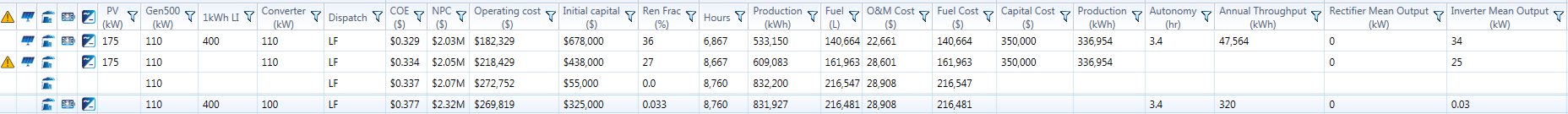


Figure : List of feasible system combinations

The optimal solution consists of a 175 kW PV array, 400 1 kWh lithium ion batteries and a 110 kW diesel generator. The renewable fraction of this system was 36 % with the battery bank have 3.4 hours of autonomy per year. The NPV of this system was $2.03 million. Although this test found an optimal solution that met all requirements it was designed to meet there was no control over assumptions such as operation time of different technologies. Although this test is easier to implement and determine the optimal hybrid system combination the lack of freedom was deemed undesirable and therefore the results of his test were not used.

**Test No: 2.0 – Manual Calculations**

Manual calculations allow the Team to have more control of certain parameters in the system and add assumptions that may not be present in software simulations. This type of test is best described as back tracking test, where the overall load power required is known for the system but the specific sizes of each technology to provided that power is unknown. However, unlike the HOMER simulations, where multiple values for each parameter can be calculated rapidly and simultaneously, the manual calculations must be performed for each change of parameter value. This type of test will only be run to determine the size of the system which includes the PV array, battery bank, inverter, boost converter and diesel generator. A key assumption that will be made during this test is the length of operation or capability of operation of each technology. This includes assumptions on how long the battery bank will be able to run the load on its own, how many hours of the day will the PV system be able to run the load and from that how many hours the diesel generator will operate due to insufficient supply from the PV array or battery bank.

Along with assumption about the operation of the technologies assumptions about the technologies themselves must be outlined. The calculations could take into account average parameter values for the technologies of the system or specific technology parameters can be obtained. This is particularly true for the PV array and the battery bank, one might use average voltage and current values of solar panels and batteries or obtain specific values for different types of solar panels and batteries. One of the main advantage this test has over the simulations test is that v-i relationships can be determined for each technology during the process of the calculations.

**Test Specifications**

The requirements that will be met during this conduction of this test include requirements (1), (2), (3) and (9). As mentioned above the load power is known prior to performing the test and therefore the manual calculations are used to determine the size of the PV array, battery bank, inverter, boost converter and diesel generator needed to supply the desired load. The nature of the test itself will therefore always meet requirements (1) and (2). The test will require obtaining voltage and current characteristic of the solar panels and batteries used in the system and therefore information about the operating temperatures can be obtained. From this the test will indirectly be able to determine whether the system is capable of operating in the harsh temperature conditions of Newman and therefore the capability of the system meeting requirement (3). Assumption about the length of operation of the renewable technology in the system will also indirectly determine how well the system meets requirement (9).

**Test Description**

Firstly, the test will require an assumption to be made on the autonomy of the battery bank. For this test, it is assumed that the battery bank will be large enough to be capable of supplying sufficient power to the load for 8 hours per day. Another assumption that must be made is the operating capability of the PV array, for this test it will be assumed that the PV array can supply enough power to both completely charge the batteries and run the pumps for 6 hours every day. The diesel generator should be sized big enough to be able to run the load for the times of the day when the PV and battery bank are unable to supply sufficient power to the load. Given the first two assumption about the operational capabilities of the battery bank and PV array it will be assumed that the diesel generator can run the system for 10 hours per day. The inverter and boost converter also require the assumption of parameters. For the inverter, it will be assumed that the amplitude modulation ratio ma will be 0.85 and the duty cycle, D, for the boost converter will be 0.5.

Once these assumptions have been made the test will require systematically working backwards from the load to determine the voltage and current relationships at the input and output of each technology. The test will also determine the number of strings of batteries and the number of batteries in series per string for the battery bank and the number of strings of solar panels and the number of solar panels in series per string for the PV array. Unlike the HOMER simulation test where multiple values for each parameter were entered at the start of the test and the simulation systematically worked through all possible combination, the manual calculations test requires updating the assumptions after every test.

Test 2.1

Assumption:

* One inverter, boost converter, battery bank and PV array to power entire load
* 100 % efficiency of all technologies used
* Amplitude modulation ratio ma = 0.85
* Duty cycle D = 0.5
* Battery bank autonomy of 8 hours per day
* 12 V at 100 Ahr batteries used
* 31.6 V and 9.57 A rated voltage and current solar panels
* 6.1 hours of full sun
* 100 % depth of discharge of batteries

Equations:

Test 2.2

Assumption:

* One inverter, boost converter, battery bank and PV array to power entire load
* 85% inverter efficiency
* 100 % boost converter efficiency
* Amplitude modulation ratio ma = 0.85
* Duty cycle D = 0.5
* Battery bank autonomy of 8 hours per day
* 12 V at 100 Ahr batteries used
* 31.6 V and 9.57 A rated voltage and current solar panels
* 6.1 hours of full sun
* 100 % depth of discharge of batteries

Equations:

Test 2.3

Assumption:

* One inverter, boost converter, battery bank and PV array per pump
* 85% inverter efficiency
* 100 % boost converter efficiency
* Amplitude modulation ratio ma = 0.85
* Duty cycle D = 0.5
* Battery bank autonomy of 8 hours per day
* 12 V at 100 Ahr batteries used
* 31.6 V and 9.57 A rated voltage and current solar panels
* 6.1 hours of full sun
* 80 % depth of discharge of batteries

Equations:

Test 2.4

Assumption:

* One inverter, boost converter, battery bank and PV array per pump
* 85% inverter efficiency
* 100 % boost converter efficiency
* Amplitude modulation ratio ma = 0.85
* Duty cycle D = 0.5
* Battery bank autonomy of 8 hours per day
* 12 V at 138 Ahr batteries used
* 31.6 V and 9.57 A rated voltage and current solar panels
* 6.1 hours of full sun
* 80 % depth of discharge of batteries

Equations:

**Test Result Analysis**

Test 2.1

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Vin (V) | Vout (V) | Iin (A) | Iout (A) | Pin (kW) | Pout (kW) |
| Inverter | 800 | 415 | 112.5 | 63 | 90 | 90 |
| Boost Converter | 400 | 800 | 225 | 112.5 | 90 | 90 |

|  |  |  |
| --- | --- | --- |
|  | # in series per string | # strings |
| Battery Bank | 34 | 18 |
| PV array | 13 | 54 |

Comments: There were too many strings of both the batteries and solar panels. As the number of strings increase the probability of difference in voltage amongst the strings increase which could cause faults in the system. Unrealistic assumption to assume all equipment exhibits 100 % efficiency.

Test 2.2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Vin (V) | Vout (V) | Iin (A) | Iout (A) | Pin (kW) | Pout (kW) |
| Inverter | 800 | 415 | 132.3 | 63 | 106 | 90 |
| Boost Converter | 400 | 800 | 264.7 | 132.3 | 106 | 106 |

|  |  |  |
| --- | --- | --- |
|  | # in series per string | # strings |
| Battery Bank | 34 | 22 |
| PV array | 13 | 64 |

Comments: As with test 2.1 there were too many strings which could lead to a fault in the system. Inverter efficiency reduced to a realistic level however 100% depth of discharge of batteries may lead to fewer charge cycles.

Test 2.3

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Vin (V) | Vout (V) | Iin (A) | Iout (A) | Pin (kW) | Pout (kW) |
| Inverter | 800 | 415 | 44.1 | 63 | 35.3 | 30 |
| Boost Converter | 400 | 800 | 88.2 | 44.1 | 35.3 | 35.3 |

|  |  |  |
| --- | --- | --- |
|  | # in series per string | # strings |
| Battery Bank | 34 | 9 |
| PV array | 13 | 27 |

Comments: Number of strings decreased which is favourable to reducing the probability of fault in the system. Equation used to determine the input voltage of the inverter may be wrong, further research will be conducted.

Test 2.4

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Vin (V) | Vout (V) | Iin (A) | Iout (A) | Pin (kW) | Pout (kW) |
| Inverter | 606 | 415 | 58.2 | 63 | 35.3 | 30 |
| Boost Converter | 303 | 606 | 116.4 | 58.2 | 35.3 | 35.3 |

|  |  |  |
| --- | --- | --- |
|  | # in series per string | # strings |
| Battery Bank | 26 | 9 |
| PV array | 10 | 35 |

Comments: reduced number of batteries and solar panels per leg of the system. Assumptions seem reasonable for the system.