Design and Analysis of Power Evacuation System for Solar Power-Plant

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Abstract

Six solar power plants on a canal are considered. 2.88-4.32 MW power is generated at each of the canal solar power plant at 3.3kV and power from all the six solar power plants is evacuated at the main receiving substation among them. The power is generated at 3.3kV voltage level and collected at 11kV at the main receiving substation. Further the received power at 11kV is stepped up to 66kV using switch yard and then dumped into the state grid. The process of collecting the power and dumping it into the desired load center is known as power evacuation. Cable is taken of 11kV and substation will be of 11/66kV.

The power flow simulation for this non-conventional energy power plant is done using ETAP software. The simulation is done in order to find the power generation losses, power availability, reliability, tentative cost and efficiency.

Keywords: *chainage, cable, PV cells, inverter, feeder, grid*

INTRODUCTION

The reason behind developing this project by using the non-conventional solar energy source is the present scenario which is to save the conventional energy sources for the future and to generate the power from the non-conventional solar energy source. Also day to day consumption of electrical energy is increasing and it is expected the requirement of energy in units will reach to 30 TW by the year 2050 so for such a high demand for energy, in the energy race solar energy will become a major player [1]. Now a day's therefore solar energy to produce power is gaining much attention and it is playing an essential role in providing clean sustainable electrical energy and also India's location is on the equatorial sun belt of the earth, thereby India receives abundant radiant energy from the sun and solar power plant has a bright future in India [2]. The power plant using the solar energy has low maintenance cost, it can be used for diverse applications, it reduces electricity bills and technology development in this field has scopes [3]. The future of solar energy consists of advancement of technologies of concentrated solar power called solar thermal and of photovoltaic (PV) because study of PV cells shows that operating temperature is indirectly proportional to efficiency of PV cell and advancement in these technologies can make the solar based system efficient [4]. The solar based systems can also be made more efficient and profitable by connecting the system with the Cloud [5]. For stand-alone PV systems case components ratings are kept low because as the load increases, the storage battery rating also increases, but this relation can be reversed using Maximum Power Point Tracking (MPPT) algorithm which in turn improves the efficiency of the solar cells. But MPPT algorithm itself needs vast development for improving its efficiency so that it can encourage domestic generation of power using solar panels [6]. Therefore single line diagram of the system was simulated using non-conventional energy that is solar energy with grid as Grid connected PV systems have become the best alternatives in renewable energy at large scale [7]. The single line diagram of solar energy power plant which is laid on a canal was simulated in the ETAP (Electrical Transient and Analysis Program) software, which includes different six chainages connected to the different feeders. PV cells for solar energy power plant are considered either on the roof tops or on the banks of the canal thus making PV array panel. The power generated at each chainage feeds the feeder present at those chainage. The power from all the chainages is evacuated and dumped into main receiving chainage and from there it is further stepped up and dumped into state grid. We concentrate on the use of grid-connected solar energy powered power plant to replace conventional sources of electricity. Calculations of this plant are also done, which includes cable sizing and transformer sizing. We can also perform these all simulations and calculations for hydro power plant and can find which one is more efficient.

SIMULATION

Chainages present in the main Single Line Diagram, in order namely are 2315 chainage, 4150 chainage, 6415 chainage, 7500/8531 chainage, 9900 chainage and 16700 chainage. On each chainage several feeders are applied. The feeders are taken as lumped load. 2315 chainage having the generation capacity of 3*1.44MW consists of 0.2MVA, 0.5MVA, 0.3MVA, 0.4MVA as lumped load respectively as shown in the Fig. 1. Similar are the details of the loads present on the rest of the chainages. The 4150 chainage having the generation capacity of 2*1.44MW consists of 0.2MVA, 0.5MVA, 0.3MVA, 0.4MVA as lumped load respectively. 6415 chainage having generation capacity of 2*1.44MW consists of 0.2MVA, 0.5MVA, 0.3MVA, 0.4MVA as lumped load respectively. 7500/8531 chainage having generation capacity of 3*1.44MW consists of 0.2MVA, 0.2MVA, 0.2MVA, 0.2MVA, 0.3MVA, 0.3MVA as lumped load respectively. 9900 chainage having generation capacity of 3*1.44MW consists of 0.2MVA, 0.5MVA, 0.3MVA, 0.4MVA as lumped load respectively. 16700 chainage having generation capacity of 3*1.44MW consists of 0.2MVA, 0.5MVA, 0.3MVA, 0.4MVA as lumped load respectively. Chainages are the power collection points from where the power is evacuated and dumped into the main receiving substation chainage i.e. 7500/8531 chainage.

The numerical name of the chainage tells about the distance between the solar power plants chainages. At each chainage photovoltaic cell (PV cell) are used. PV cell in the ETAP software is available with in-built inverter. This set of PV cell and inverter convert the solar energy to the direct current and that direct current is turned to the alternating current. For PV cells, ETAP software settings are done so as they yield maximum output in form of the alternating current. The power collected at the main receiving substation at 11kV is stepped up to the 66kV voltage level and to which grid and a capacitor bank are connected in service in mode while keeping few PV cells out of service. This is done because if all the PV cells and the grid are kept in service, PV cells do more generation than the total power required because of which the grid or generator in ETAP start taking the excess power assuming that as extra and start satisfying the load and the generator starts acting as motor i.e. the reverse power starts flowing. Therefore few PV cells are kept out of the service. So the grid provides the active power to the system as not all of the PV cells are kept in service mode and the reactive power required by the system is provided by the capacitor bank. The chainages are connected with each other using two inter-connections so that system is reliable but at the same time it makes the system more costly. At a time only one connection is kept in the working mode in the ETAP software. Cables are considered for power transmission purpose. The length of the cables used to connect the chainages in the given order as above mentioned are 1.84km, 2km, 2.40km, 0.50km, 7km respectively.

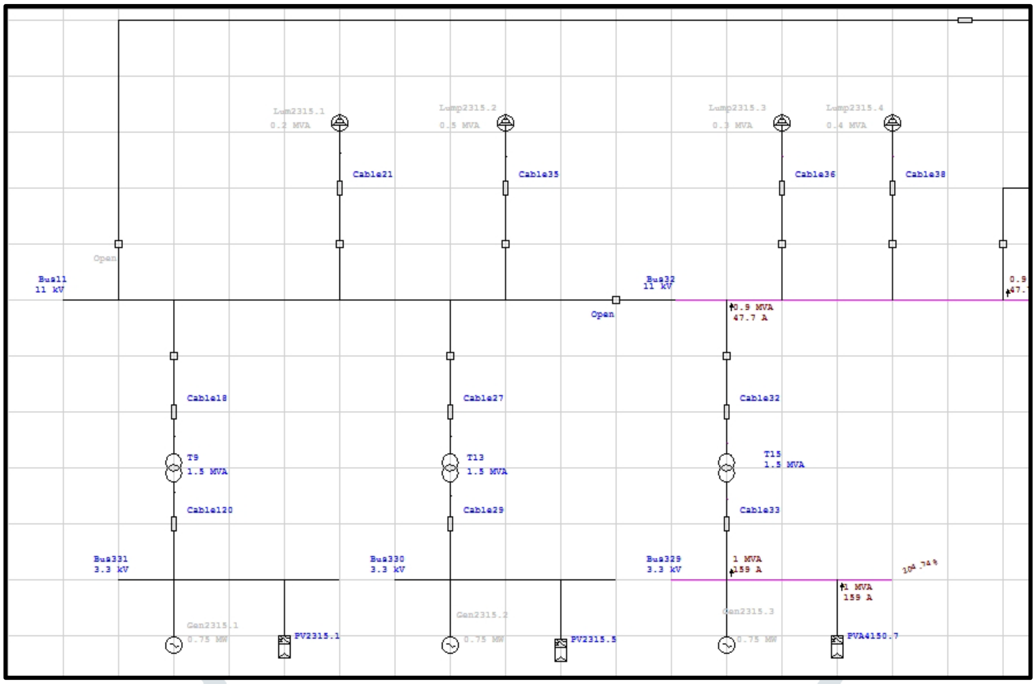

Fig. 1: *2315 Chainage*

Two cases done after the inter-connections are done are as follows:

A. With feeders

For this case all the feeders that are lumped loads applied on each chainage are kept in service and no load are applied on the 66kV line. The total lumped load available on the chainages equals to 8.4MVA. The power flow that we get in % form is 94.95 at 11 kV line.

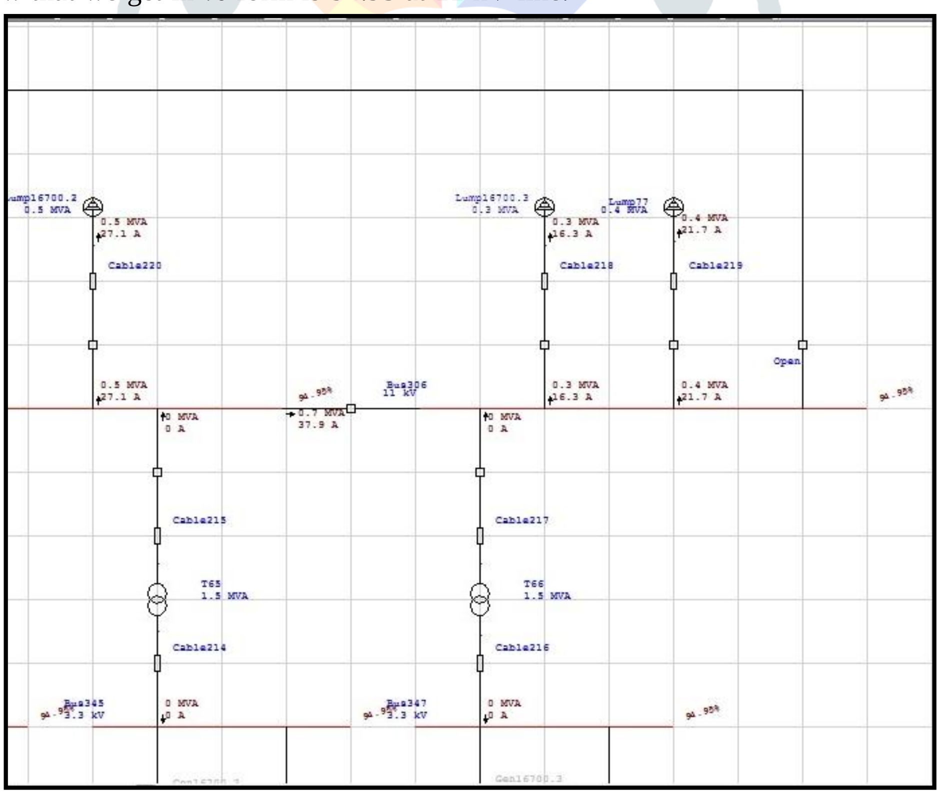

Fig. 2: *with feeders' case*

B. Without feeders

For this case all the feeders that are lumped loads applied on each of the chainage are kept out of service and total of 8.4MVA load is applied on the 66kV line so that the transformer is loaded 70% to 75% of its MVA rating and therefore 11/66kV transformers doesn't get de- rated. 4.2MVA and 4.2MVA are applied on both the 11/66kV transformers so that equal load sharing is there. The power flow that we get in % form is 100% which less than 105% and this is permissible and such case occasionally occurs.

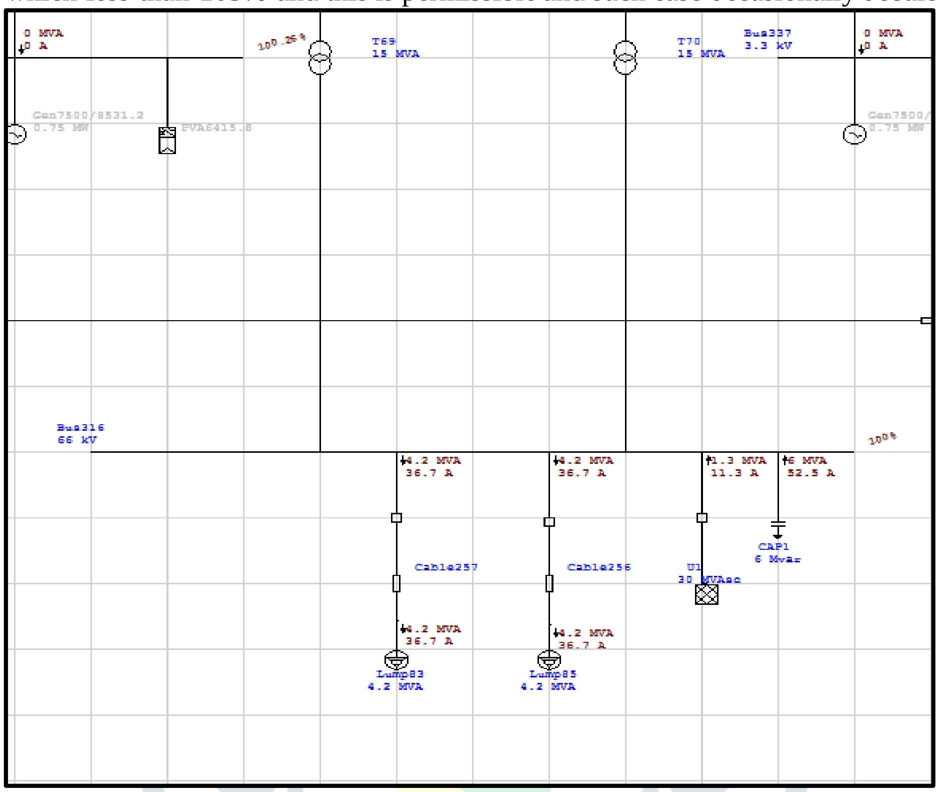

Fig. 3: *without feeders' case*

CALCULATIONS

A. Cable Sizing

Two types of conductor arrangements that are trefoil and flat arrangement are considered. For each of these cases ground and air case are considered. In flat case for ground and air 66 kV calculations are only done because for 3.3 kV and 11 kV flat formation cables are not available. Explaining about the first calculation done which is 3.3 kV trefoil ground and air case. Considering the ground case first feeder maximum loading is achieved from main SLD's one of the line and that is equal to 49.9A. De-rating factor for ambient temp 45 deg and conductor operating temp 90 deg, cable in ground in trefoil formation and cable are advised to under-load then rated capacity are the values taken from CCI catalogue. Cable in ground in trefoil formation value comes out to be 0.88 for ground. On multiplying all the three above factors give the total correction factor that is 0.5984. From the CCI catalogue the cable with the minimum cross-section is selected that is 150sq mm. Current carrying capacity for 150sq mm from the CCI catalogue came out as 245A for ground case. By multiplying the total correction factor with this current carrying capacity we get the cable capacity arrived. As cable capacity arrived is greater than the feeder maximum loading (from SLD) therefore we can say that cable will not de-rate fast and this is desired. For second part that is for air, the calculations are done in the same manner, but for cable laid in air in trefoil formation is taken as 0.95 and current carrying capacity of 3.3kV 150 sq mm is taken as 290. For that also cable sizing is done. Similarly all other calculations are done.

Table 1: *3.3kV 3-core cable trefoil ground case calculations*

1. Feeder maximum loading (from SLD)	49.9A
2. De-rating factor for ambient temperature 45 degree and conductor operation temperature 90 degree.	0.8
3. Cable laid in ground in trefoil formation, restricted air circulation and two circuits in vertical.	0.88
4. Cable are advised to under-load then rated capacity.	0.85
5. Total correction factor	0.5984
6. Current carrying capacity of 3.3kV, 150 sq mm.	245
7. Cable capacity array	146.608

Table 2: *3.3kV 3-core cable trefoil air case calculations*

1. Feeder maximum loading (from SLD)	49.9A
2. De-rating factor for ambient temperature 45 degree and conductor operation temperature 90 degree.	0.8
3. Cable laid in air in trefoil formation, restricted air circulation and two circuits in vertical.	0.95
4. Cable are advised to under-load then rated capacity.	0.85
5. Total correction factor	0.646
6. Current carrying capacity of 3.3kV, 150 sq mm.	290
7. Cable capacity array	187.34

B. Transformer Sizing

The total load is 8.4 MVA and 30% more than that should be the transformer rating i.e. 10.4MVA rating for the transformer but minimum MVA value for the transformer available in ETAP is 15MVA and therefore that value is taken. Transformer sizing for the transformer connected to the 66kV bus is done so that it doesn't get de-rate and has a long life. Therefore, we load transformer 70% to 75% only and the total load on the feeders is 8.4 MVA which is less than 70% of 15MVA.

RESULTS AND DISCUSSION

The power flow that we get in % form is 94.95 for the "with feeders' cases" and the power flow that we get in % form is 100 for the "without feeders' cases". This shows that the losses are more in the "with feeders' case". Also the solar power plant is more efficient in the day time as compared to the night.

CONCLUSIONS

Solar power plant installation is costly but if once built; its returns are higher with low operating costs, since their major input sunlight is free and solar power plant has a great future in India like countries. Solar power plant as a stand-alone plant has more payback period i.e. almost 80% and this is more than any other non-conventional energy stand-alone power plants' payback, say for a hydro power plant payback period will be 40%. But if the two i.e. solar and hydro power plants if together used in a combination then this combination will be able to provide the power to the loads for full year without using any other source. But Grid connected PV systems are the best alternatives in renewable energy at large scale. Single line diagram simulations for the other non- conventional energy power plants can also be done for example for hydro etc. and can be compared with the solar plant calculations so as to see which power plant is more efficient in power flow.

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