Determination of Photovoltaics Hosting Capacity of 33kV Network in Province No. 1, Nepal

Ashish Nepal, Nawraj Bhattarai

Abstract— **The unpredictable nature of output of alternative energy sources like Solar PV often become troublesome for the smooth operation of electrical energy transmission/distribution system. Hence, before interconnecting such sources to the transmission/distribution network, it is necessary to assess if the variation power quality parameters of the hosting system (Hosting Capacity) lies within the standard criterion. This study identifies the hosting capacity of Photo-Voltaic systems in a 33 kV network of Integrated Nepal Power System in Province No. 1, Nepal. Time domain load flow has been carried out to study the system margins to accommodate given size of photo voltaic system. Load flow simulation are also carried out for both Wet and Dry season indicating times with excess and scarce generation in the system. The size of the generating units fed to two different buses are gradually increased and the hosting capacity has been analysed. It is seen that, with existing infrastructures, installation of generating units up to 30 MWp is suitable.**

Index Terms— **Hosting Capacity, Photovoltaics, Load Flow**

I. INTRODUCTION

Nepal is a water rich country with plenty of hydropower generation potential. Having techno economically viable potential of hydropower of about 43 GW [1], Nepal would have been abundant supplier of energy amid chances of exporting energy to neighboring countries India and china. Conflict to this there exist sluggish development of hydropower in the country, leading to power and energy deficit and country suffering from significant power cuts even few years ago. As most of the hydro power lies far from load center transmission and distribution of bulk amount of power is challenging due terrain, unclear policies, political interest, escalation of land prices etc. Difficulties in constructing transmission and distribution lines has direct impact on quality of power. The effects are usually, low voltage, in urban areas due to unavailability of suitable place to construct substation and in rural areas due to long feeder lengths.

To fulfill gap of sluggish development of main stream hydropower plants, transmission and distribution lines investment in renewable energy resources in technical, economical, policy and social level, have now become vital. To overcome deficit in quality of power supply installation of Distributed Generation (DG) in distribution feeders and transmission grids have become increasingly popular and is being practiced in many parts of the world. Although being rescuer to many issues the excessive injection of DG system into an existing electrical networks may cause many problems and operational limits violations under and over voltages, violation of thermal rating of conductors, excessive line losses, overloading of transformers, disturbance in protection coordination, harmonic distortion and other standards set by the utilities. Therefore before connecting DG into a network it is inevitable to evaluate systems capacity so as to determine how much of injection the system can host before violating performance limits which is most commonly known as Hosting Capacity (HC) of the network and can be understood most basically as maximum amount DG penetration at which power system operates satisfactorily [2]. This thesis attempts to calculate HC of Province No 1 of Nepal.

Over last two decade there have been unparalleled development in renewable energy sector all over the world. Several countries have adopted support schemes as feed-in tariff, green subside, micro grids, roof top solar and tax exemption as well. Compiling to all these scenarios electricity utilities are forced to respond to the excessive demand to provide their networks for DG connection and at the same time ensuring that interconnection doesn’t violate technical standards of existing network. When the local DG interconnection exceeds the capacity of line and substation especially during lightly loaded condition traditional one way power flow from substation to feeders to low voltage distribution lines are supplemented by reverse power flow and power fed into upstream networks. Such conditions sources several other problems including low power factor in medium voltage and high voltage substations, voltage regulations and high short circuit capacity. Thus utilities should determine first in fast simplified and reliable manner that what is the HC of the particular feeder and distribution network [3] [4] [5]. Renewable energy interconnection arises in different form in a network sometime as rooftop solar, as a PV modules directly to distribution feeders as a wind turbine and sometime even as hybrid network. DG might be of any type but before approving interconnection in the network utilities must go through screening process to determine potential adverse effect of such connection which can often be time consuming and requires attention of the regulators. With high demand of interconnection awaiting it has become essential for utilities to promptly analyze the entire feeder and determine its HC analyzing risk before normal operation of the distribution system are violated and power quality remains within normal standards.

Determining HC is not a straight forward process as it may varies according to location or point of interconnection, to the type of DG added to the system. The value of HC once calculated for certain feeder’s changes even when the configuration of feeder is changed and power system equipment upstream and downstream changes.

In correlation with around the world, Nepal is also expecting potential amount of DG interconnection as an isolated system mini grid and to Integrated Nepalese Power System (INPS). So, it is wise to investigate potential amount of DG before real

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works of installation begins. Such studies have been carried out in different grids [6] [7]. Few studies have been carried out to determine HC in a single 11 kV feeders originating from certain substation. This study highlights and attempts to calculate one of the DG solar HC of the entire Province No. 1 of Nepal. This work gets its value added as Nepal is in elementary phase of implementing Federalism and Government has just began the process of deregulation. An attempt has been made in this paper to determine operational characteristics of grid connected large scale solar PV in Province No. 1 of Nepal. This paper also discusses about challenges of integrating large scale PV in power grid. The power system grid for Province No. 1 has been simulated in ETAP software. This paper has been divided into four sections. Section II presents the methodology of the work carried out. The results obtained are presented and analyzed in Section III. Section IV compiles the conclusion.

II. METHODOLOGY

This study is focused on determining the HC of a PV in Power System network of Province No. 1 of Nepal. The power system of Province 1 has been modelled at first. Time-domain load flow has been carried out for two scenarios, dry season, i.e. low generation, high demand and wet season, i.e. high generation and low demand. However, the demand doesn't vary much in dry and wet season in Nepal. The variation in generation is the result of hydropower dominated power system of Nepal.

A. Modelling of the network.

For the purpose of the study, the power system of the selected region has been Modelled in ETAP. The information regarding the generation, transmission system and load has been obtained from the Nepal Electricity Authority((NEA)) [8], which is the government owned body currently looking after the generation, transmission and distribution of electric power in Nepal.

The system modelled in ETAP consists of the following.

- Number of Buses: 47
- Number of Branches: 64
- Number of Generating Stations: 12
- Number of Loads: 25

Fig. 2 shows the model developed in ETAP, an electrical simulation software. For the ease of study, the part of network west to the Dhalkebar substation of Nepal has been modelled as an electrical power grid in ETAP. This has been done specifically as, both transmission line from Upper Tamakoshi Hydropower and Dhalkebar-Muzzaffarpur line converge at Dhalkebar substation. The load data was collected from (NEA) and modeled in the system. Similarly, the line parameters were also added from the collected data.

B. Base Case Load Flow Analysis

The ETAP software has multiple options for carrying out load flow analysis. In this case, the load flow was first attempted using Newton-Raphson method. Later on, Adaptive Newton-Raphson method, available in the ETAP software was used for the load flow analysis. The base case load flow analysis was carried out for Wet and Dry Season. Nepalese power system is primarily a hydro-dominated power system. The wet season sees abundance of generation with increase in water flow in the river. The dry season on the other hand, sees less generation with decrease in water flow in the rivers. The wet season is typically during June and July with increase in water flows in river due to monsoon rainfall. Whereas, the dry season is typically during February and March when the river water level is to minimum level. The load dispatching mechanism in INPS is looked after by Load Dispatch Centre (LDC) of (NEA). Currently Nepal has a single water reservoir Hydro Electric Project, namely Kulekhani Hydro Electric Plant (KHEP). (KHEP), combinedly Kulekhani I and Kulekhani II add up to 60 MW. (NEA) uses this hydroelectric project as system reserve. In practice, (KHEP) is sometimes used to supply the peak demand during peak hours. The results of both the wet and dry season load flows are presented in Section III. The solar PV was connected to the existing system in two different locations. The load flow was then carried out with step increment of Solar PV Capacity. The detail methodology for the Load Flow with Solar PV is discussed in subsequent sub-section.

C. Load Flow with Step Incremental of PV Farm.

Load flow analysis is performed with step increase in PV generation in the designated sites during 6:00 to 18:00 without altering the loading. For each step increase in PV size, loss, voltage profile and expected reserve and power swing (at slack bus) is observed. The constraint (Reserve and the Ramping of the Slack bus) is related to the system reserve and ramping rate. With same loading condition, injecting the intermittent PV cause counter swing of slack bus to balance the power.

While designing the PV, the PV power generation in a typical cloudy day of March is presented in the Fig.1. It is observed that, there is fluctuation of generated power from 0.96 pu to 0.48 pu during 13:00-14:00-15:00 hours.

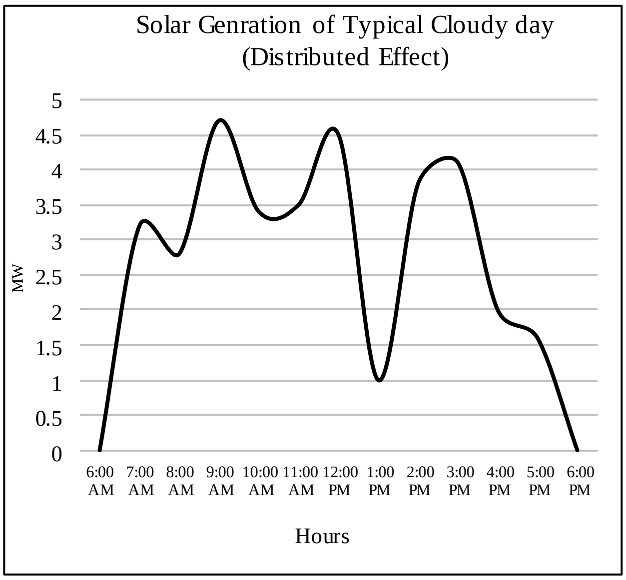

Figure 1: A typical PV Output all-round the day

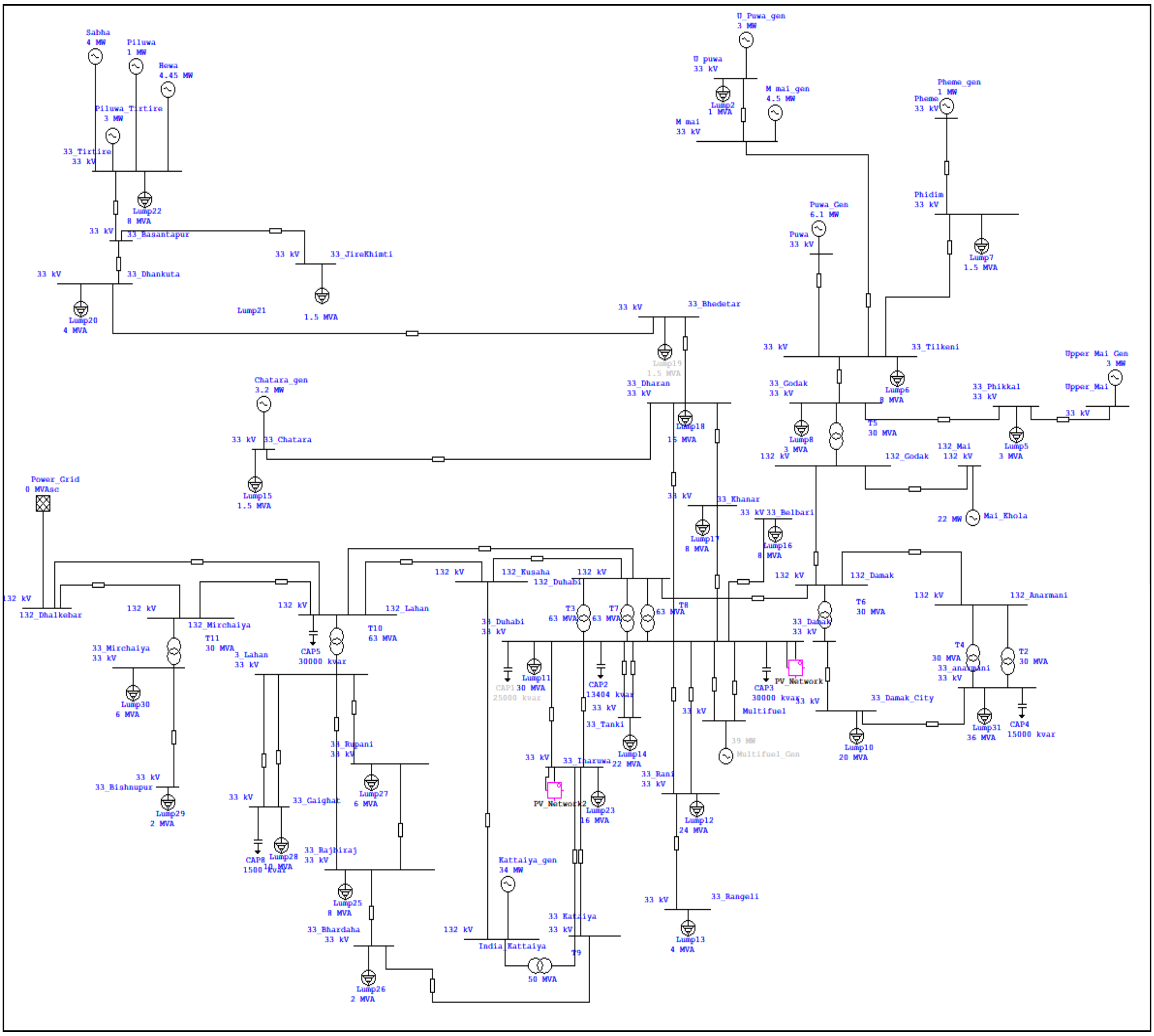

Figure 2: Designed Network of Province No. 1 of Nepal in ETAP

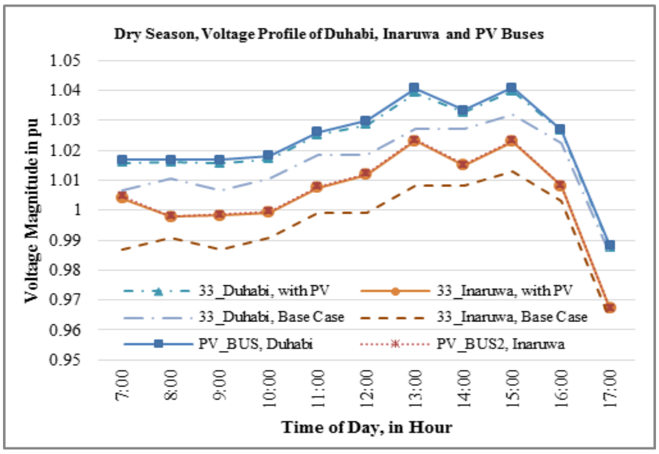

Figure 3: Voltage Profile of Weak Buses, with and without PV Injection in dry season

The effect of the PV generation will have to release equal power from the swing bus considering the same loading condition. Considering this constraint time domain load flow for both dry and wet season was performed. The PV of 1 MW each was connected to the system in both the locations. In this manner, step increase of PV was carried out in both locations.

III. Results and Discussion

A. Load Flow of Dry Season

During the dry season, for a typical dry and hot day. Load Dispatch Centre (LDC) of (NEA), manages to run its generator meeting the maximum load with minimum reserve as the water level in (KHEP) is in lower side.

Thus, the important operation scenario is not to deteriorate existing operating and reserve condition, or PV generation should not demand additional reserve. In this scenario, the upper ceiling of PV installation will be around 60MWp.

In case of our study region, there exists a Duhabi Multifuel, with a capacity of 39 MW. This can be also considered as system reserve for this region.

Additionally, the system reserve in that area would be around 39 MW Multifuel. Considering the constraint, we go on increasing the PV size in step of 4x1 MW and evaluated the operational variables.

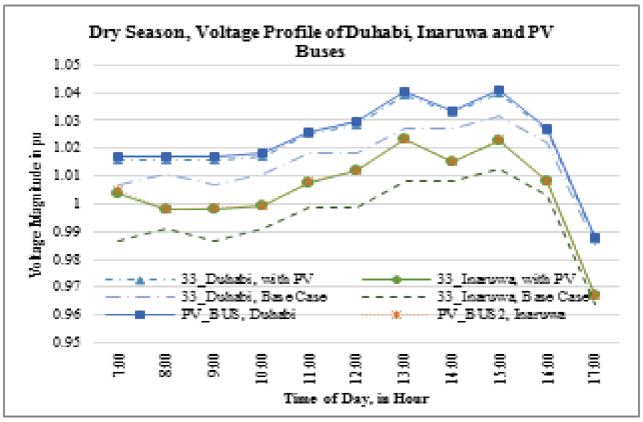

Figure 4: Voltage Profile of Duhabi, Inaruwa and PV Buses, for base case and with PV Injection in Dry Season

The PVs were connected to 33_Inaruwa and 33_Duhabi bus. The PV were injected into the system were incremented in step size. Initally, larger size (4x1MW) was considered and the system loss was monitored. After an increase in system loss was observed, the incremental size was decreased and the size of PV suitable for injection in the system was determined. Fig. 3 depicts the curves for system losses with and without PV Injection at 15:00 hours during a dry season. It is clear that, the system losses decrease until PV injection is increased up to 30 MWp. System Losses start to increase with increase in PV Injection increasing from 30MWp.

Thus, the maximum PV size that can be injected to the Province 1 power system is considered to be 30 MWp. This is well within the limit of the system reserve available at the location.

Next step was to verify the ability of the system to handle the 30MWp solar input. Time domain load flow was carried out with PV injection to the system in both dry and wet season. Fig.4 shows the voltage profile of 33_Inaruwa, 33_Duhabi and PV Buses during a typical day of a dry season. The voltage magnitudes during the evening tend to fall towards 0.95. The existing situation of the system shows that, the system peak lies during 18:00 hour and the voltage magnitude is much lower during the peak hour. Nepal Electricity Authority is carrying out different projects to upgrade the power delivery capacity to these regions.

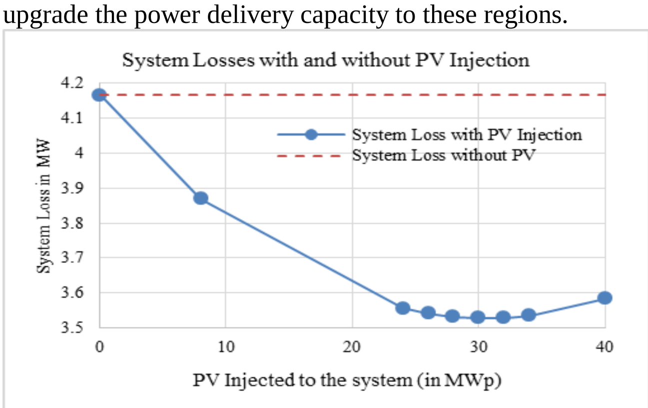

Figure 5: System Losses in Dry Season, with and without PV Injection at 15:00 hour

The injection of Solar PV has improved the voltage magnitudes in the weak buses of the system. Fig. 5 shows the voltage magnitude of the weak buses in the system obtained from the Time domain load flow from hours 6:00 to 17:00. During the later hours, the voltage drop is due to the increase in system load. The PV generation lowers during the later hours and this drop of voltage has not been addressed in the study.

In addition to the dry season time domain load flow, similar load flow has also been carried out for the wet season.

B. Load Flow of Wet Season

During wet season most of the generating units of both Independent Power Producers (IPP) and (NEA) runs at rated capacity. Usually, the Kulekhani Storage HEP is kept at standby at most of the time, i.e. at 0 MW. Similarly, the multifuel plant at Duhabi is also generally at 0 MW. During the power swing in the PV, enough reserve margin is available in the system. The rivers have increased flow and hence, the power generated in the HEPs in this region is also increased to 87MW from 76MW during the dry season. As a result the power flow from the Swing bus to the system decreases.

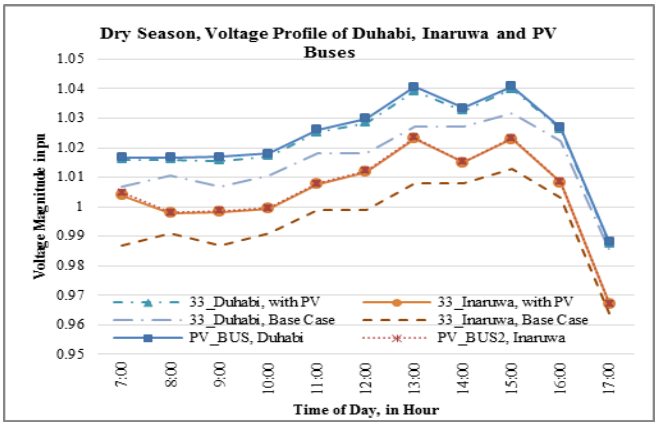

Figure 6: Voltage Profile of Duhabi, Inaruwa and PV Buses, for base case and with PV Injection in Wet Season

It is essential to consider in this time that, the voltage criteria are not violated by the injected PV system.

Time domain load flow has been carried out for a typical day of the wet season (a day in July) and the voltage profiles of the system has been observed. Fig. 6 shows the voltage profile of PV buses and Duhabi and Inaruwa bus, to which the PVs are connected. It can be observed that, the buses do not violate the Voltage criteria. It was also observed that, the line flows before and after the PV connection do not violate the line limit of the system.

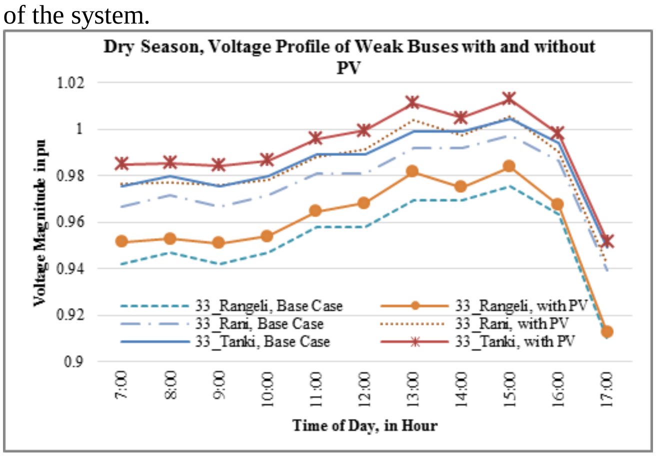

Figure 7: Voltage Profile of Weak Buses, with and without PV Injection in Dry Season

Fig. 8: Voltage Profile of Weak Buses, with and without PV Injection in Wet Season

The injection of Solar PV has improved the voltage magnitudes in the weak buses of the system. Fig. 7 shows the voltage magnitude of the weak buses in the system obtained from the Time domain load flow from hours 6:00 to 17:00. During the later hours, the voltage drop is due to the increase in system load. The PV generation lowers during the later hours and this drop of voltage has not been addressed in the study.

IV. Conclusion

In this study, the power system network of Province 1 was modelled in ETAP. Load flows were carried out considering Dhalkebar Substation as System Swing Bus. Time-domain load flow has been carried out for two scenarios, dry season, i.e. low generation, high demand and wet season, i.e. high generation and low demand though, the demand doesn't vary much in dry and wet season in Nepal.
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The existing situation of the system shows that, the system peak lies during 18:00 hour and the voltage magnitude is much lower during the peak hour. During wet season most of the generating units of both Independent Power Producers (IPP) and (NEA) runs at rated capacity while the case is reverse in dry season. The injection of Solar PV has improved the voltage magnitudes in the weak buses of the system
The Solar PV were installed in two locations Inaruwa and Duhabi. The size of Solar PV were increased in subsequent simulations and it was observed that, installation of Solar PV up to 30 MWp is suitable in this system. It is hence, concluded that, the HC of PV of Province 1 Power System Network of Nepal is 30 MWp.

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