Analysis of Renewable Energy Penetration Impact in Power system and Recommendations for Bangladesh

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ABSTRACT

The aim of this thesis paper is to find the safe limit of penetrating renewable energy to the grid. For this purpose the effects of the renewable energy penetration to the grid is studied thoroughly. Also the different integration techniques for different kind of renewables are studied and the best suited technique for solar pv generator is picked which is "The Hybrid Power Plant" with the aid of power electronic devices. To perform analyses the "New England 39 Bus Test System" is chosen and by replacing the convenient fossil fuel generators by solar pv generators different penetration level is achieved. Four different penetration level namely 10%, 20%, 30% and 40% are modelled and then load flow studied are done. Later results are analysed thoroughly and the conclusion about the safe penetration limit is decided. Finally keeping in mind the upcoming renewable energy scenarios of Bangladesh all the estimate suggestions for a safe and sound renewable energy penetration are made. All the models of the test system are modelled in ETAP 16.0 and the load flow studies are done in the same program.

Keywords- Hybrid power system, transient stability study, critical clearing time, swing curve, ETAP software.

1. INTRODUCTION

In 1882 Edison inaugurated the first central generating station in the USA. The Edison plant fed a load of 400 lamps, each of them consuming the power of 83 W. At about the same time the Holborn Viaduct Generating Station in London was the first in Britain to cater for consumers generally, as opposed to specialized loads. This scheme used a 60-kW generator driven by a horizontal steam engine; the voltage of generation was 100V direct current (DC). The first major alternating current (AC) station in Great Britain (GB) was at Deptford, where power was generated by machines of 10 000 h.p. and transmitted at 10 kV to consumers in London. During this period the battle between the advocates of AC and DC, it was the War of Currents era (sometimes, War of the Currents or Battle of Currents). George Westinghouse and Thomas Edison became adversaries due to Edison's promotion of DC for electric power distribution against AC advocated by several European companies and Westinghouse Electric based in Pittsburgh, Pennsylvania, which had acquired many of the patents by Nikola Tesla. Owing mainly to the invention of the transformer the supporters of AC prevailed and steady development of local electricity generating stations commenced with each large town or load center operating its own station. In 1926, in Britain, an Act of Parliament set up the Central Electricity Board (CEB) was created with the object of interconnecting the best of the 500 generating stations then in operation with a high-voltage network known as the Grid. The act tried to link the Britain most efficient power stations with consumers via a 'national gridiron'. The CEB established the Britain first synchronized AC grid, running at 132 kilovolts (kV) and 50 Hertz (Hz), which by 1933 was a collection of local grids, with emergency interlinks, covering most of England. Nationalization of the electricity supply industry under terms of the Electricity Act 1947 comes into effect in 1948.The Electricity Act 1947 nationalized 505 separate electricity generation and supply organizations in GB on 1 April 1948, both privately owned and state-owned, and consolidated them into 14 area electricity boards of the new Central Electricity Authority that the Act created (also known as the British Electricity Authority), which subsequently became the Central Electricity Generating Board [1].

2. HYBRID POWER SYSTEM

Hybrid power systems are designed for the generation and use of electrical power. They are independent of a large, centralized electricity grid and incorporate more than one type of power source. They may range in size from relatively large island grids of many megawatts to individual household power supplies on the order of one kilowatt [2]

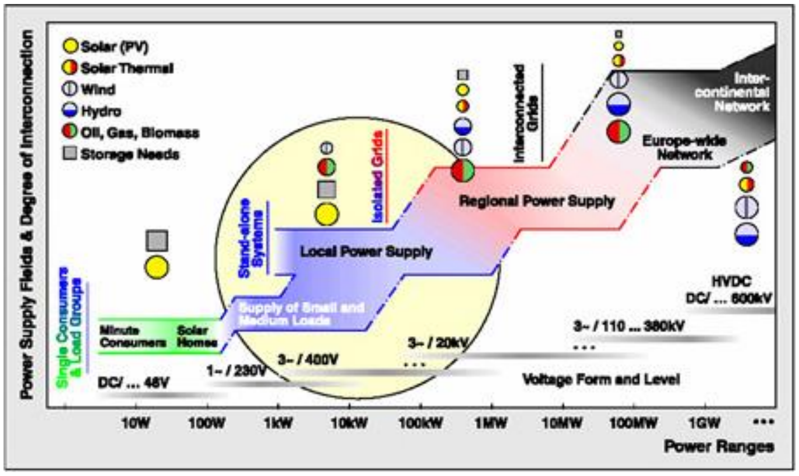

Figure 1: Hybrid power system

Hybrid power systems that deliver alternating current of fixed frequency are an emerging technology for supplying electric power in remote locations. They can take advantage of the ease of transforming the AC power to higher voltages to minimize power loss in transferring the power over relatively long distances. Isolated AC systems include at least the following: conventional AC diesel generators, an electrical distribution system, and distributed AC loads. A hybrid system could also include additional power sources such as renewables (wind turbines, photovoltaic panels) and storage. Note that storage is actually both a source and a load [3].

3. METHODOLOGY

ETAP software is being used to design a hybrid power system and to determine the critical clearing time [14-16]. The whole simulation process is given in figure2.

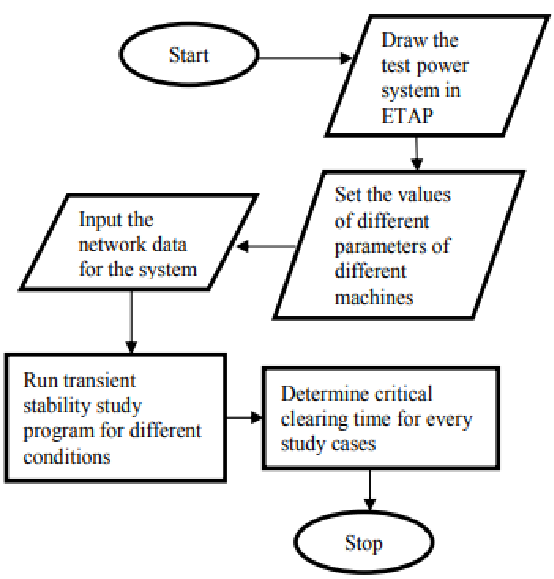

Figure 2: Flow chart of the simulation process

4. RESULT ANALYSIS AND DISCUSSION

4.1. ACTIVE POWER FLOW

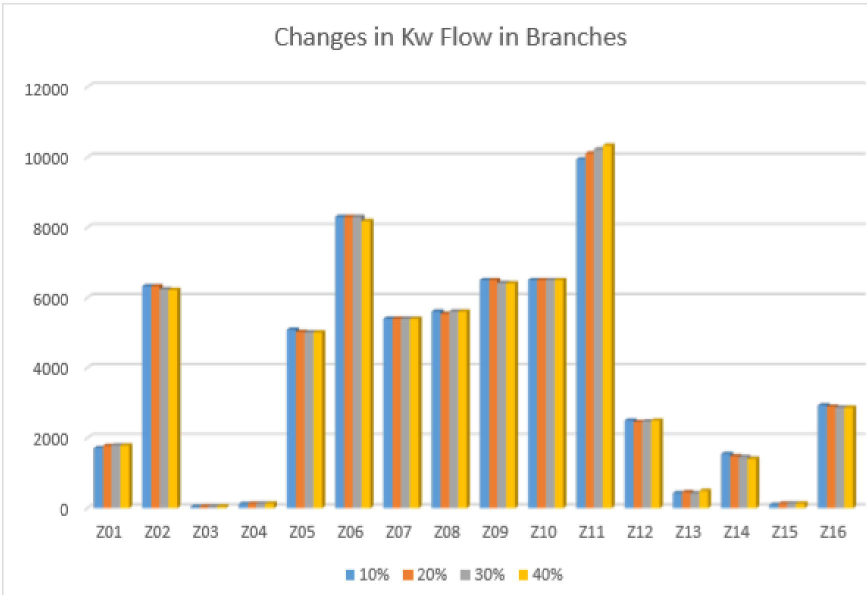

Figure 3:Changes in Kw Flow in Branches Z01-Z16

There are 46 branches i.e transmission lines are in the New England 39 Bus Test System. These branhes are lebeled as Z01-Z46. Figure 3-5 are representing the changes in active power flow i.e kw flow in the branches. We should note that the energy which is being integrated to the grid is purely active.

Which means that the active power flow in these transmission lines are not going to be hampered as severely as the reactive power flow is going to be [4]. The figures suggests that the changes in the branches are minimal. There are few branches where changes are considerable but in most branches the changes are unnoticeable.

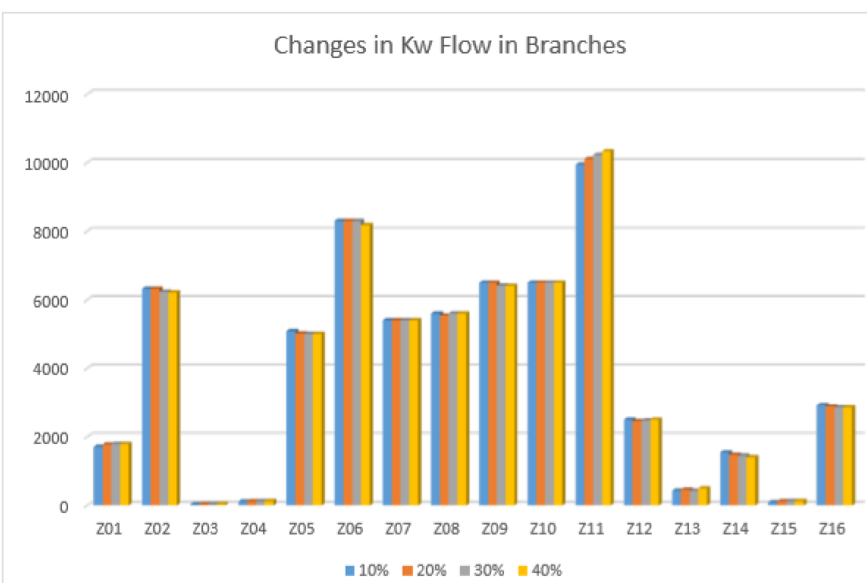

Figure 4: Changes in Kw Flow in Branches Z17-Z32

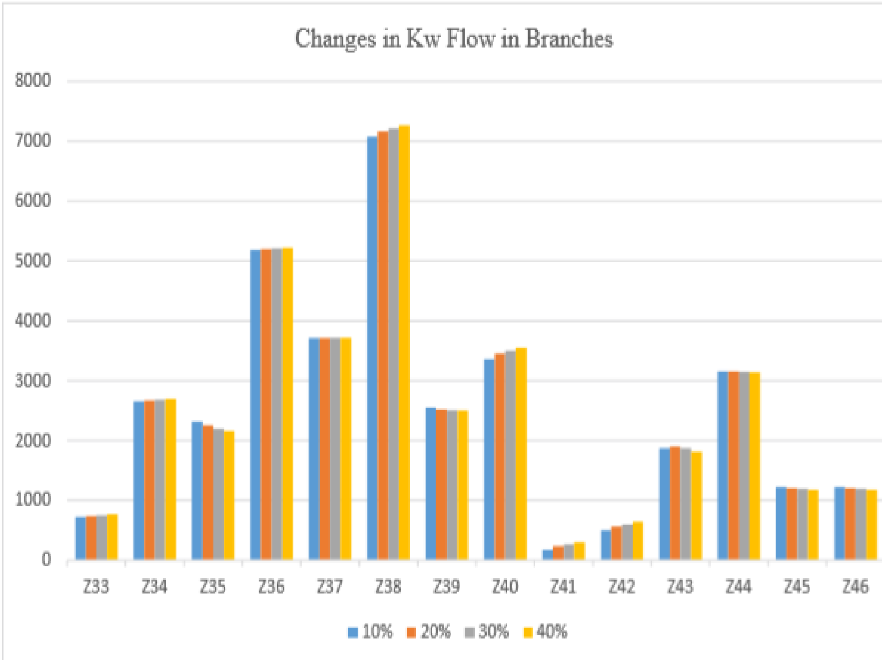

Figure 5: Changes in Kw Flow in Branches Z33-Z46

4.2. CHANGES IN CURRENT FLOW

Figure 6 and 7 are representing the changes in ampere flow in the branches. Again at minimum level of penetration the changes are not significant. But at higher level of penetration the ampere flows are increasing for some branches and decreasing for some other while is constant for some branches throughout the different penetration level [5]. This also suggests that the power factor at higher level of penetration is improving for some branches while its becoming poor for some other.

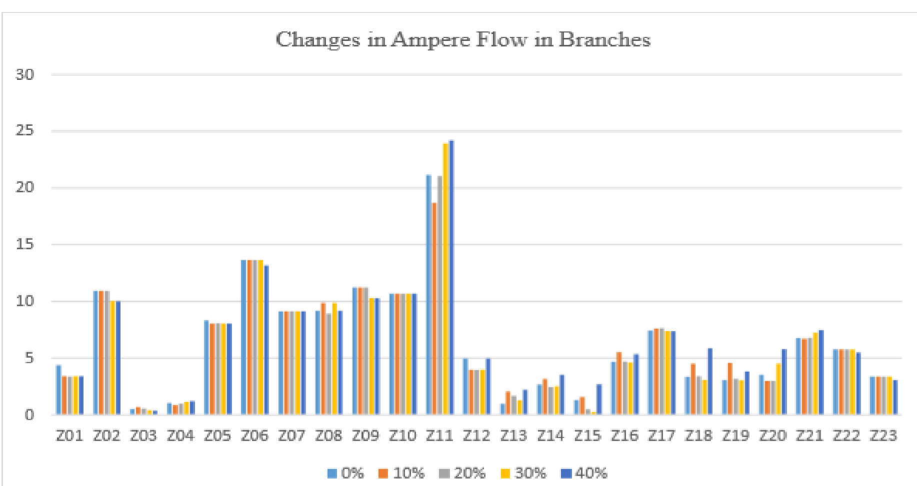

Figure 6: Changes in Ampere Flow in Branches Z01-Z23

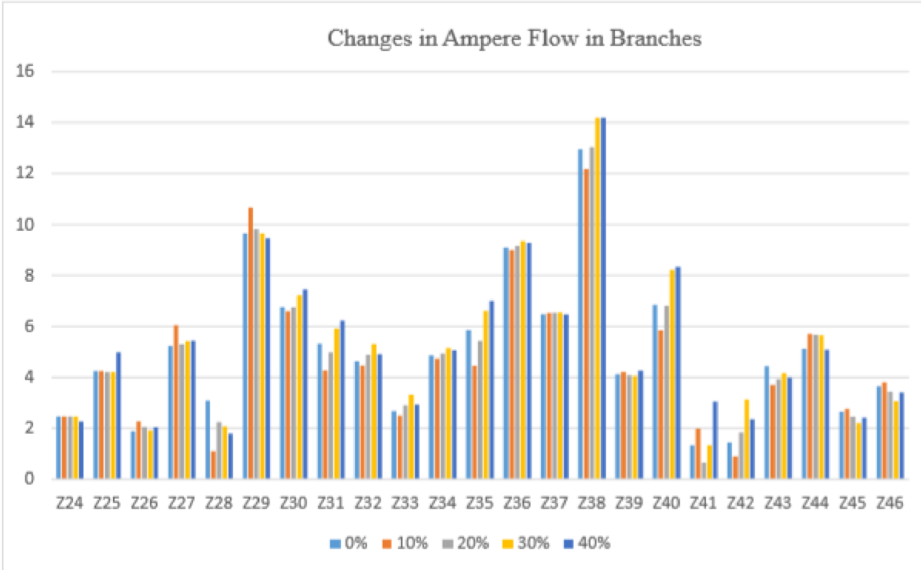

Figure 7: Changes in Ampere Flow in Branches Z24-Z46

4.3. REACTIVE POWER LOSS

On contrary to the active power loss, the changes in reactive power loss is not significant at all. With the increase in penetration level the loss is almost identical to the bas case as if no renewable energy is penetrated at all. Figure 8 and Figure 9 are representing the reactive power loses that occurs in the branches with the base case i.e no solar energy penetrated and with the different penetration levels of the solar energy namely 10%, 20% ,30% or 40% of the total energy present in the grid [6].

This behaviour is due the fact that there is barely enough reactive power to support the active power flow. No additional reactive power is present to be wasted. Also with the increase of solar pv in the system the number of reactive component in the system present is becoming less which decreasing the reactive power loss.

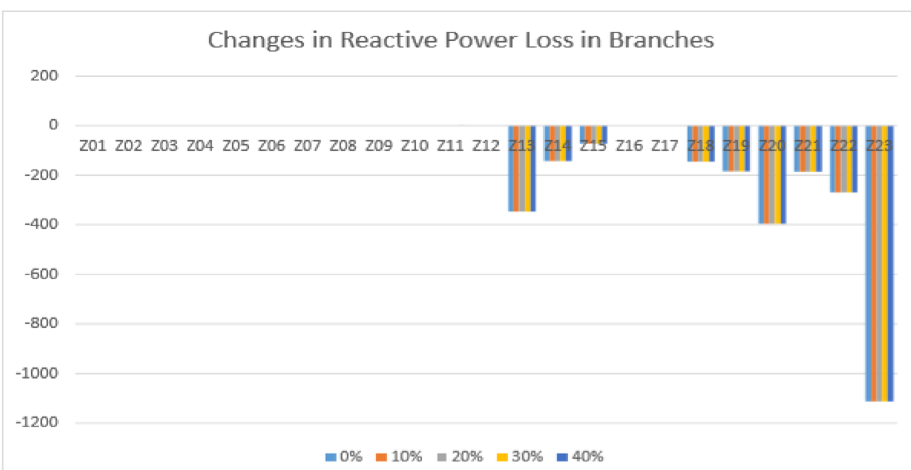

Figure 8: Changes in Reactive Power Loss in Branches Z1-Z23

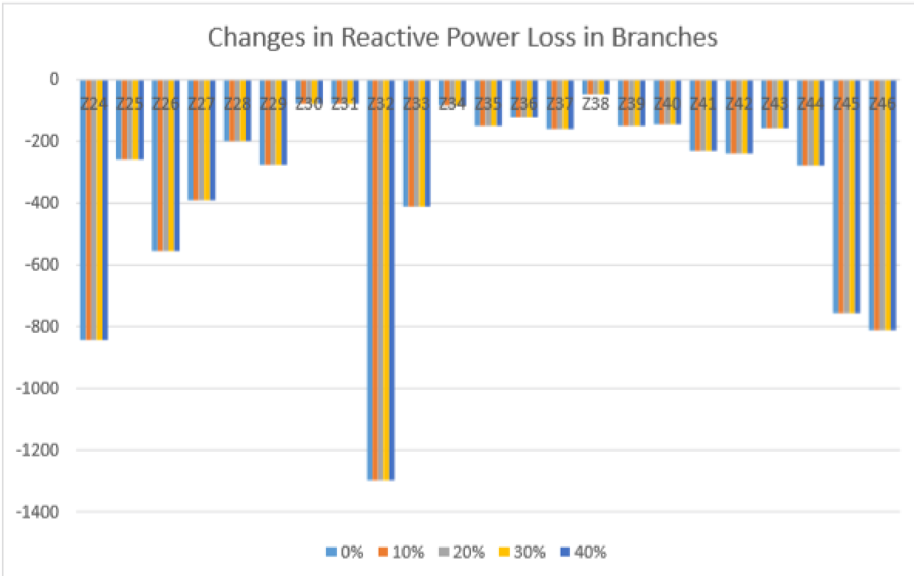

Figure 9: Changes in Reactive Power Loss in Branches Z24-Z46

4.4. ACTIVE POWER LOSS

Figure 10 and Figure 11 are representing the active power loses that occurs in the branches with the base case i.e no solar energy penetrated and with the different penetration levels of the solar energy namely 10%, 20% ,30% or 40% of the total energy present in the grid [7].

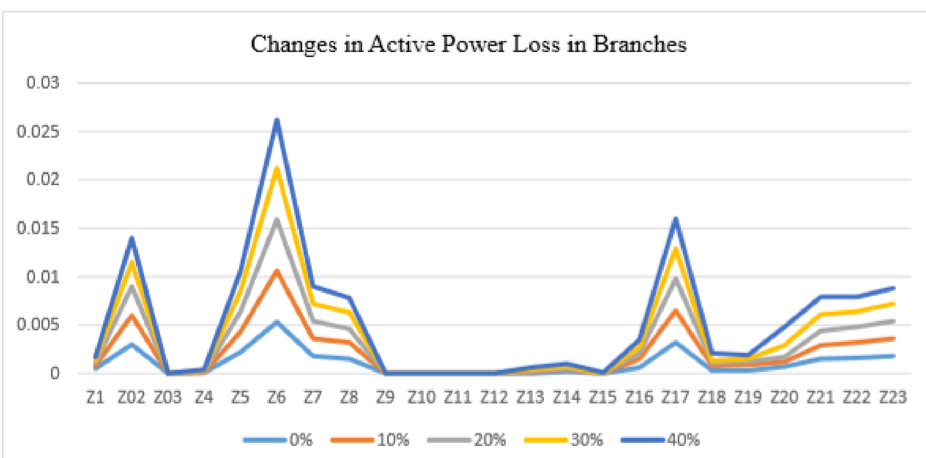

Figure 10: Changes in Active Power Loss in Branches Z1-Z23

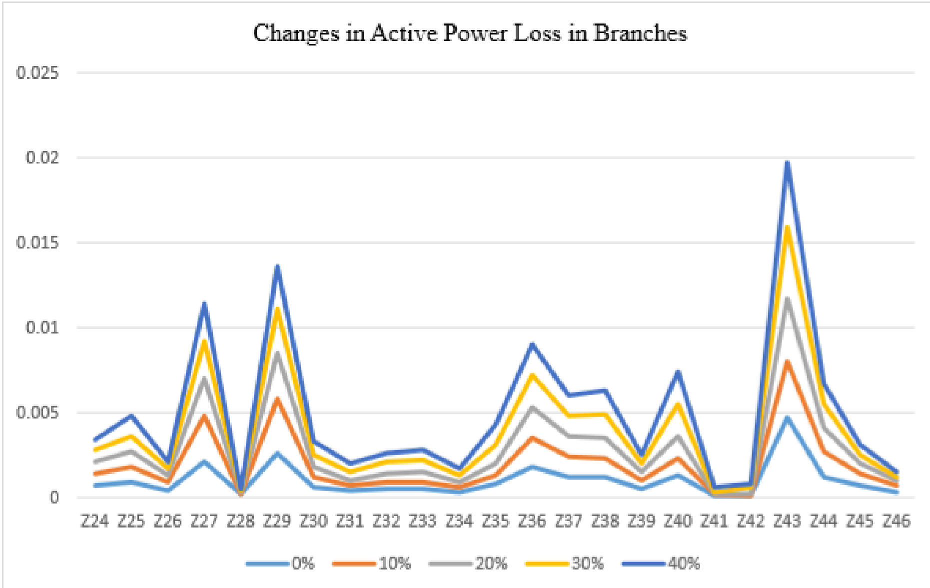

Figure 11: Changes in Active Power Loss in Branches Z24-Z46

4.5. REACTIVE POWER FLOW

As discussed in the previous section , since the integration method only integrate real power without any reactive power support the kvar flow in the transmission lines are going to vary drastically [8].

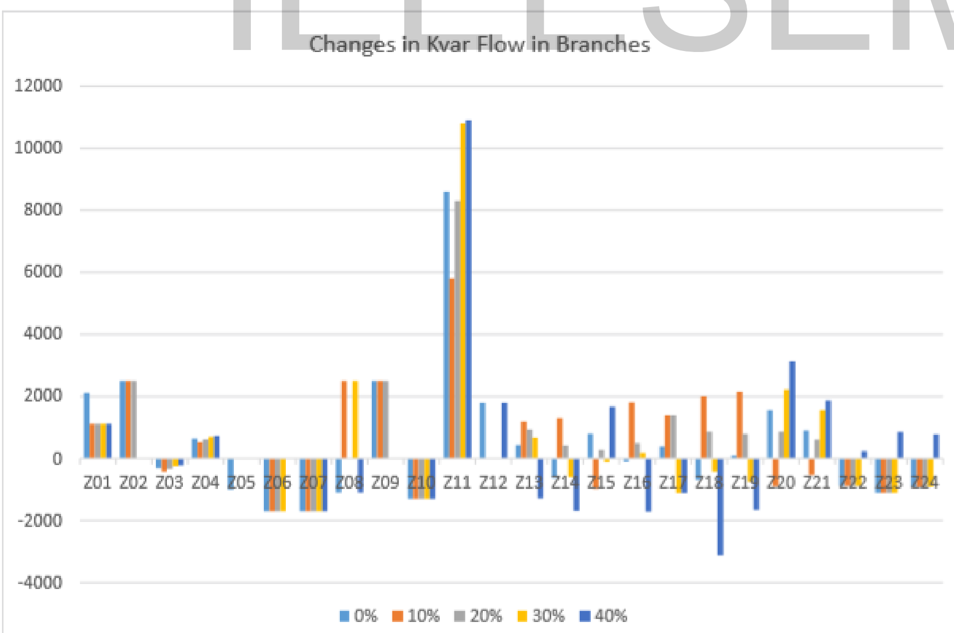

Figure 12: Changes in Kvar Flow in Branches Z01-Z24

Figure 12- Figure 13 are representing the changes in kvar flowing in the transmission lines. As these three figures suggest as the level of penetration increases the kvar loading changes from its original value. At low level penetration i.e. 10% ,

the changes are not severe for most of the branches. But as the penetration level increases the kvar flow readings varies significantly from the base case which is no solar penetration at all.

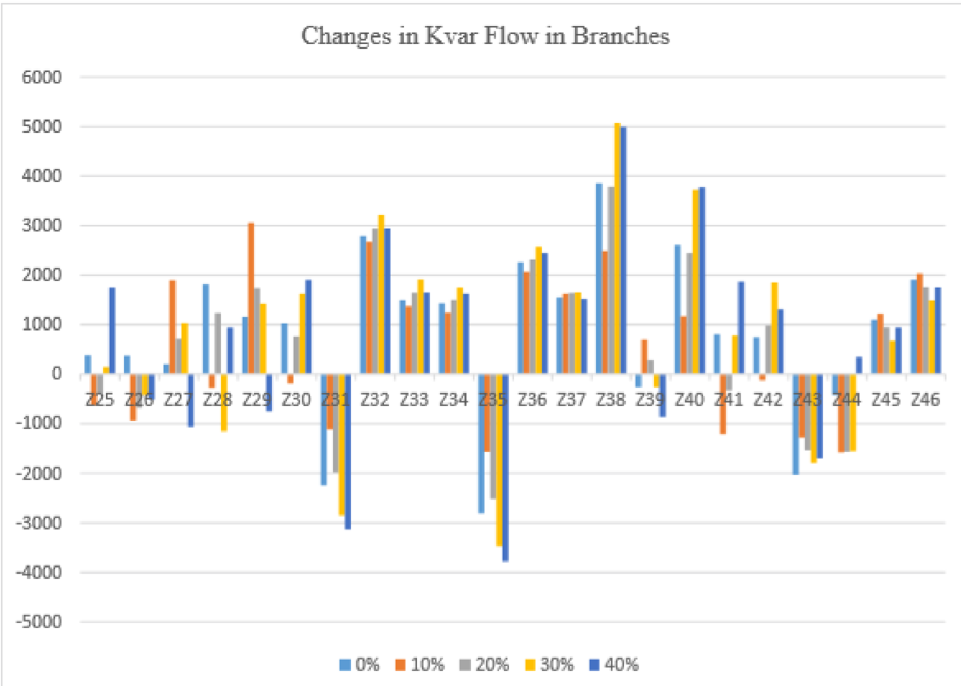

Figure 13: Changes in Kvar Flow in Branches Z25-Z46

4.6. RECOMMENDATIONS FOR BANGLADESH

When it comes to generating green energy, Bangladesh's past performance has seen a mix of success and failure. The government did not attain its goal of generating five percent of the country's electricity from renewable sources by 2015; but that did not deter it from continuing to aim high. The government is now eyeing a target of generating 10% of its power from renewable resources by 2020 [9]. Bangladesh is currently generating around 560 MW of electricity from renewables, which is just 2.95% of total power generation. Experts reckon generating 2000 MW of power—10% of the total— within two years, will be challenging. However, many efforts have already been made to attain the goal [10].

Presently, a total of 559.80MW of power is generated from renewable energy, of which a whopping 325.82MW, or 52.8%, comes from solar power. Keeping that in mind which aligns with our thesis; the findings we have can directly be prescribed for Bangladesh [11]. Since Bangladesh is aiming for 10% penetration level by 2020 which is actually a low level penetration limit the suggestion will be [12]:

I. The Integration Should be at Distribution Level
II. Power Electronic Devices should be used as integration method.
III. The Hybrid Power Plant method can be considered as well.
IV. All necessary precautions should be taken for security measures as the integration will affect short circuit current level, reverse power flow, islanding and a whole set of new protection problem.
V. Harmonics, frequency regulation, flicker and other power quality problems shouldn't bother at such low level of intergration but the grid code must be followed.
VI. The need of reactive power support must be evaluated even at such level of integration.

5. REFERENCES

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