Grid Analysis using PSAT Software

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Abstract

Power flow analysis is the backbone of power system analysis. This research paper evaluates the value of magnitude and phase angle of voltage at each node/bus and the real and reactive power flowing in each transmission line between the interconnected buses. To execute this analysis, there are techniques of mathematical calculations that have lots of steps depending on the size of the system. This process is time consuming and difficult to perform by hand because lots of calculations and iterations are involved this paper covers the modelling and the transient stability analysis of the Grid by using Matlab Power System Analysis Toolbox (PSAT) package.

Keywords: Power System Analysis Toolbox (PSAT), Voltage Stability, Smart Grid, Flexible AC Transmission System (FACTS)

I. INTRODUCTION

Reliable and affordable electrical power is essential to the modern society. The modern electrical power systems cater the demands in wide range of areas which include the major components such as generators, transformers, transmission lines, motors and etc. The availability of new advanced technologies has made a smarter, more efficient and sustainable grid to ensure a higher reliability of electrical power supplied to mankind. Regarded as the next generation power grid, smart grid has transformed the interconnected network between electricity consumers and electricity suppliers. The smart grid system involves transmission, distribution and generation of electricity. In a smart grid, the operation of power systems infrastructure has evolved into a dynamic design instead of a static design.

As smart grid technology and its adoption are expanding throughout the world, realization in smart grid protection is important. Protection plays an important role to ensure realization of power grid reliability, security, and efficiency in generation, transmission, distribution and control network. Voltage problems have been a subject of great concern during planning and operation of power systems due to the significant number of serious failures believed to have been caused by this phenomenon. It is therefore necessary to develop Voltage stability Analysis (VSA).

In this paper we are experimenting with the designing, performance and the expansion of Madakkathara 400kV substation with the inclusion of renewable energy resources by the way of simulation, Fault Analysis, Voltage Stability Analysis and addition of Renewable Energy Resource based on the results revealed.

II. SIMULATION

The first step is modelling the components of the power system and establishing the single line diagram in PSAT software and gives the necessary data. Next step is load the file and solve the load flow analysis with Newton Raphson for different load level. Simulate the model power flow solution and save results in figures and texts. The figure given below shows the single line diagram of Madakkathara 400kV substation.

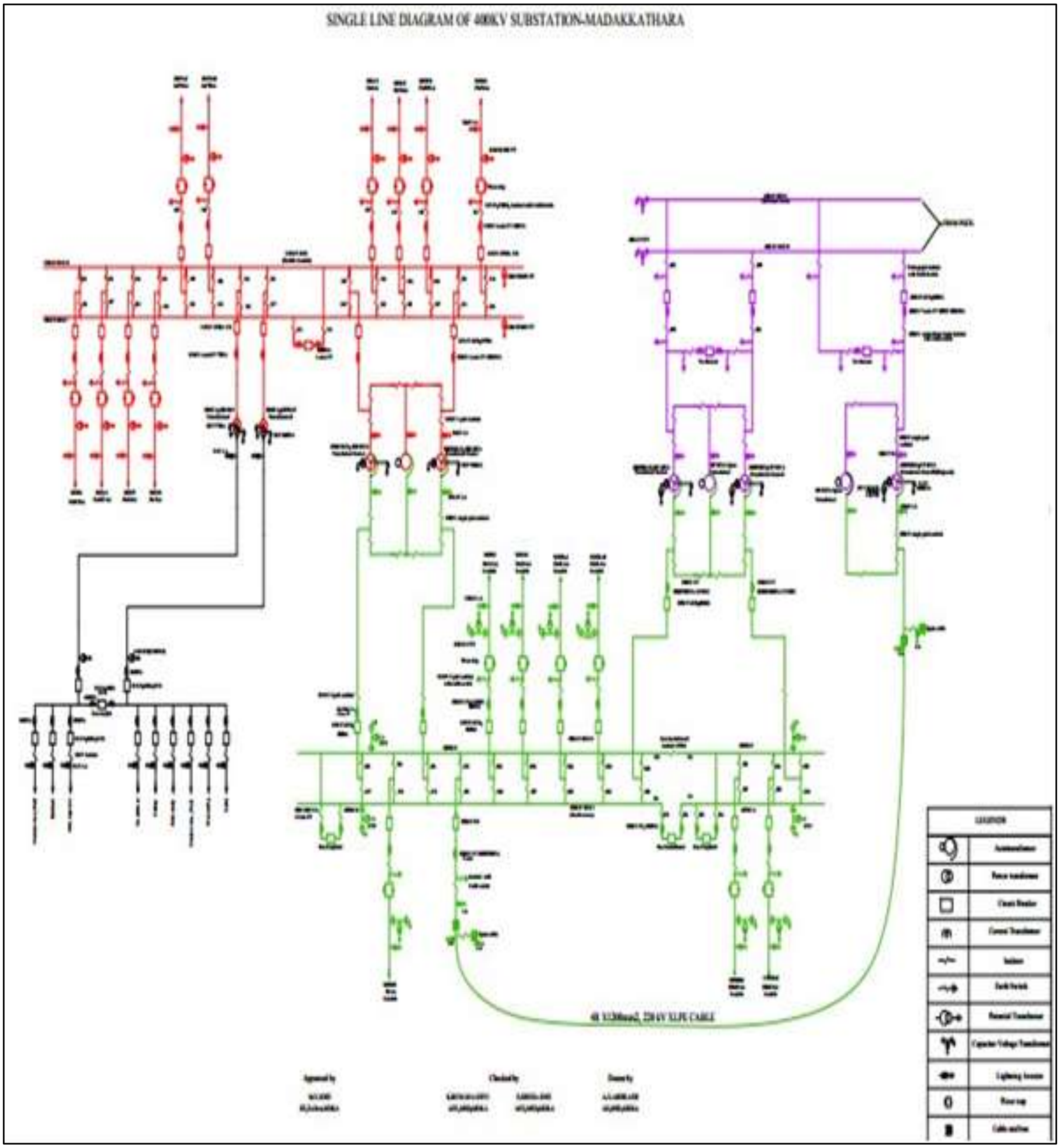

Fig. 1: Single line diagram of Madakkathara 400kV substation

III. SIMULATION RESULT

After implementing the single line diagram on PSAT software run the power flow to determine the systemstable or not. The sys tm will be stable when the bus voltage lie between 0.9-1.1p.u. The figure shows below is the single line diagram of Madakkathara 400kV substation drawn in PSAT software.

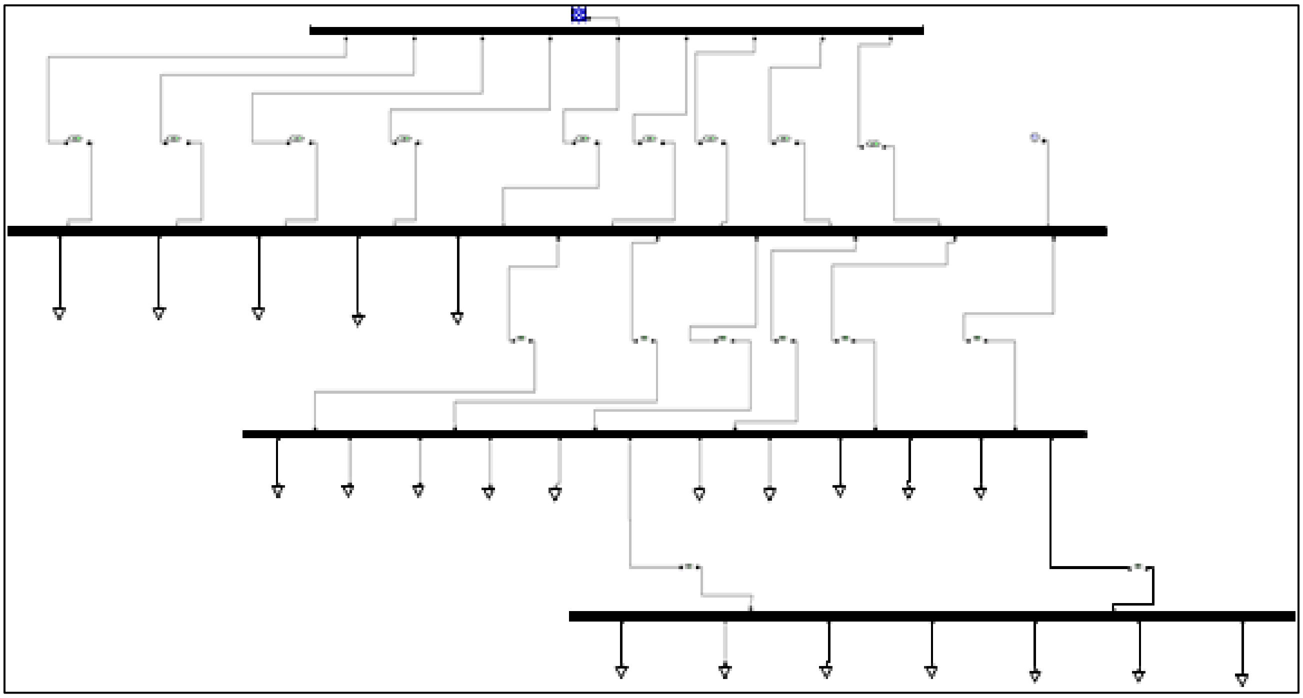

Fig. 2: Single line diagram of Madakkathara subsation drawn in PSAT

Simulation analysis specified the network statistics of Madakkathara substation and it is displayed in the below tables.

Table – 1
Simulation Result

NETWORK STATISTICS						
Buses:			4			
Transformers:			17			
Generators:			2			
Loads:			3			
SOLUTION STATISTICS						
Number of Iterations:			4			
Maximum P mismatch [p.u.]			0			
Maximum Q mismatch [p.u.]			0			
Power rate [MVA]			100			
POWER FLOW RESULTS						
Bus	V	phase	P gen	Q gen	P load	Q load
	[p.u.]	[rad]	[p.u.]	[p.u.]	[p.u.]	[p.u.]
PGCL 400KV	1.06	0	5.816431	2.909477	0	0
MDKA 110Kv	0.967986	-0.18426	0	0	1.62	0.54
MDKA 11KV	0.939483	-0.22662	0	0	0.306	0.24
MDKA 220 KV	1	-0.11917	0.8	1.329151	4.64	2.45
LINE FLOWS						
From Bus	To Bus	Line	P Flow	Q Flow	P Loss	Q Loss
			[p.u.]	[p.u.]	[p.u.]	[p.u.]
PGCL 400KV	MDKA 220 KV	1	0.64627	0.32328	0.004647	0.092946
MDKA 220 KV	MDKA 110Kv	2	0.32243	0.15869	0.001291	0.025829
MDKA 220 KV	MDKA 110Kv	3	0.32243	0.15869	0.001291	0.025829
MDKA 220 KV	MDKA 110Kv	4	0.32243	0.15869	0.001291	0.025829
MDKA 220 KV	MDKA 110Kv	5	0.32243	0.15869	0.001291	0.025829
MDKA 220 KV	MDKA 110Kv	6	0.32243	0.15869	0.001291	0.025829
MDKA 220 KV	MDKA 110Kv	7	0.32243	0.15869	0.001291	0.025829
MDKA 110Kv	MDKA 11KV	8	0.15343	0.12857	0.000428	0.008569
MDKA 110Kv	MDKA 11KV	9	0.15343	0.12857	0.000428	0.008569
PGCL 400KV	MDKA 220 KV	10	0.64627	0.32328	0.004647	0.092946
PGCL 400KV	MDKA 220 KV	11	0.64627	0.32328	0.004647	0.092946
PGCL 400KV	MDKA 220 KV	12	0.64627	0.32328	0.004647	0.092946
PGCL 400KV	MDKA 220 KV	13	0.64627	0.32328	0.004647	0.092946
PGCL 400KV	MDKA 220 KV	14	0.64627	0.32328	0.004647	0.092946
PGCL 400KV	MDKA 220 KV	15	0.64627	0.32328	0.004647	0.092946
PGCL 400KV	MDKA 220 KV	16	0.64627	0.32328	0.004647	0.092946
PGCL 400KV	MDKA 220 KV	17	0.64627	0.32328	0.004647	0.092946
LINE FLOWS						
From Bus	To Bus	Line	P Flow	Q Flow	P Loss	Q Loss
			[p.u.]	[p.u.]	[p.u.]	[p.u.]
MDKA 220 KV	PGCL 400KV	1	-0.64162	-0.23033	0.004647	0.092946
MDKA 110Kv	MDKA 220 KV	2	-0.32114	-0.13286	0.001291	0.025829
MDKA 110Kv	MDKA 220 KV	3	-0.32114	-0.13286	0.001291	0.025829
MDKA 110Kv	MDKA 220 KV	4	-0.32114	-0.13286	0.001291	0.025829
MDKA 110Kv	MDKA 220 KV	5	-0.32114	-0.13286	0.001291	0.025829
MDKA 110Kv	MDKA 220 KV	6	-0.32114	-0.13286	0.001291	0.025829
MDKA 110Kv	MDKA 220 KV	7	-0.32114	-0.13286	0.001291	0.025829
MDKA 11kV	MDKA 110Kv	8	-0.153	-0.12	0.000428	0.008569
MDKA 11kV	MDKA 110Kv	9	-0.153	-0.12	0.000428	0.008569
MDKA 220 KV	PGCL 400KV	10	-0.64162	-0.23033	0.004647	0.092946
MDKA 220 KV	PGCL 400KV	11	-0.64162	-0.23033	0.004647	0.092946
MDKA 220 KV	PGCL 400KV	12	-0.64162	-0.23033	0.004647	0.092946
MDKA 220 KV	PGCL 400KV	13	-0.64162	-0.23033	0.004647	0.092946
MDKA 220 KV	PGCL 400KV	14	-0.64162	-0.23033	0.004647	0.092946
MDKA 220 KV	PGCL 400KV	15	-0.64162	-0.23033	0.004647	0.092946
MDKA 220 KV	PGCL 400KV	16	-0.64162	-0.23033	0.004647	0.092946
MDKA 220 KV	PGCL 400KV	17	-0.64162	-0.23033	0.004647	0.092946
GLOBAL SUMMARY REPORT						
TOTAL GENERATION						
REAL POWER [p.u.]			6.616431			
REACTIVE POWER [p.u.]			4.238628			
TOTAL LOAD						
REAL POWER [p.u.]			6.566			
REACTIVE POWER [p.u.]			3.23			

Based on the simulation result, we look forward for fault analysis, voltage stability analysis and addition of renewable energy resource to extend the Madakkathara grid.

A. Fault Analysis

Fault analysis aims to determine the causes that have led to certain failure to take preventive measure to avoid that .It is Important to emphasis dual function of fault analysis. Here, we are applying fault on 220kv bus which is shown in Fig.3. All the parameters of Slack bus, Transformers and load are kept same as were in above base model of Madakkathara substation.

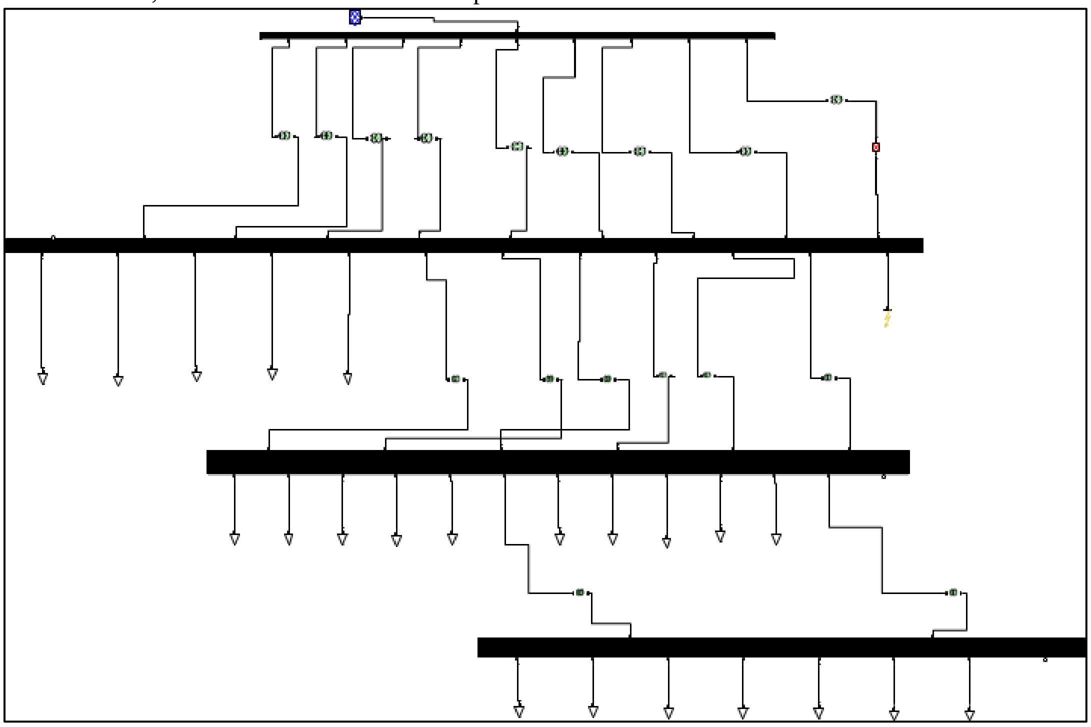

Fig. 3: Fault Analysis

The Voltage profiles of all buses are studied at different Fault clearing time. Main aim is to find the critical clearing time of fault in 220kv bus. In table 2, we are applying fault is applied at 1sec and clearing time at 1.6sec. From the figure 4, we can see that system become unstable because voltage of 11kv bus goes beyond the value 0.9p.u.

Table – 2
Fault Clearing Time

FAULT	FAULT CLEARING TIME
1sec	1.6 sec

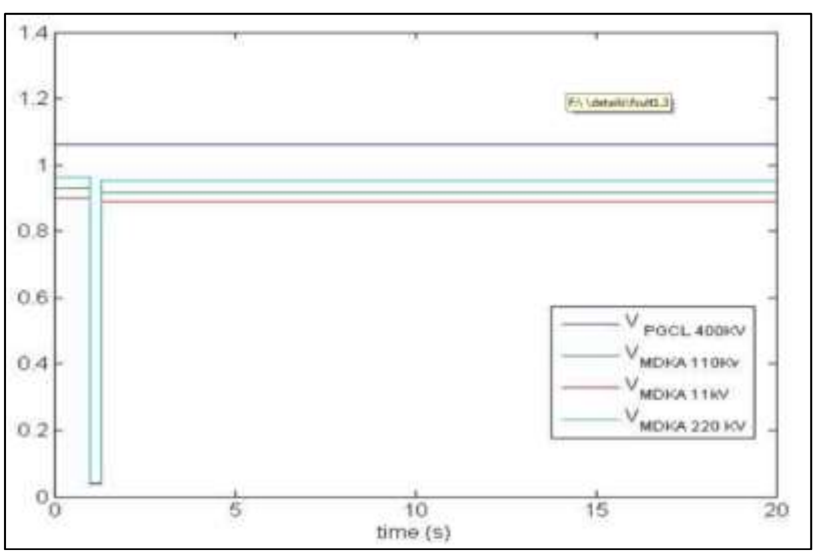

Fig. 4: Bus voltage graphical representation when fault clearing time is at 1.6 seconds

In table 3, we are applying fault at 1 sec and the clearing time at 1.3sec. From the figure 5, we can see that the system is stable. All buses lies between the range 0.9 to 1.1p.u.

Table - 3
Fault clearing time

FAULT	FAULT CLEARING TIME
1sec	1.3sec

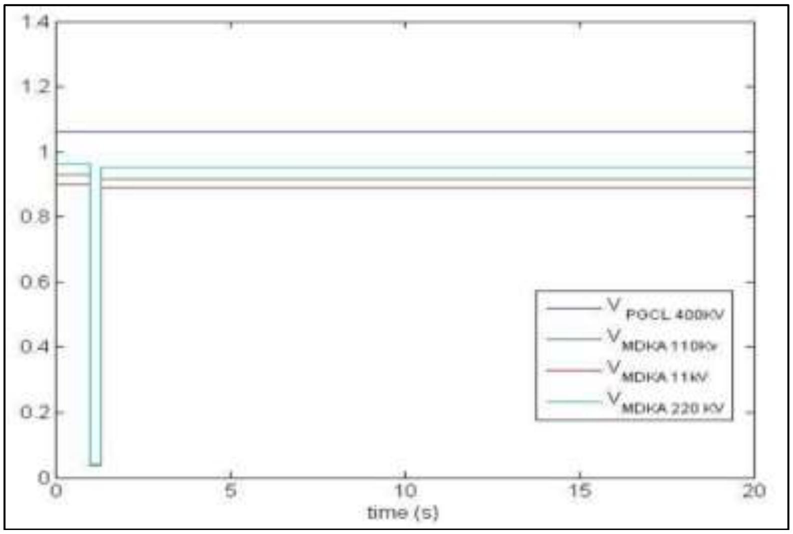

Fig. 5: Bus voltage graphical representation when fault clearing time is at 1.3 seconds

The system is stable when we clear the fault at 1.3seconds. So the critical clearing time of the system is 1.3 seconds.

B. Maximum Load Stability

Voltage stability is also known as Load stability. The power systems are heavily stressed due to increased loading and this leads to voltage stability problem. The Maximum Load that can be given to the system will be the multiple of 3.9 with the actual load value. After the value 3.9 the system will be unstable which is shown in the figure 6.

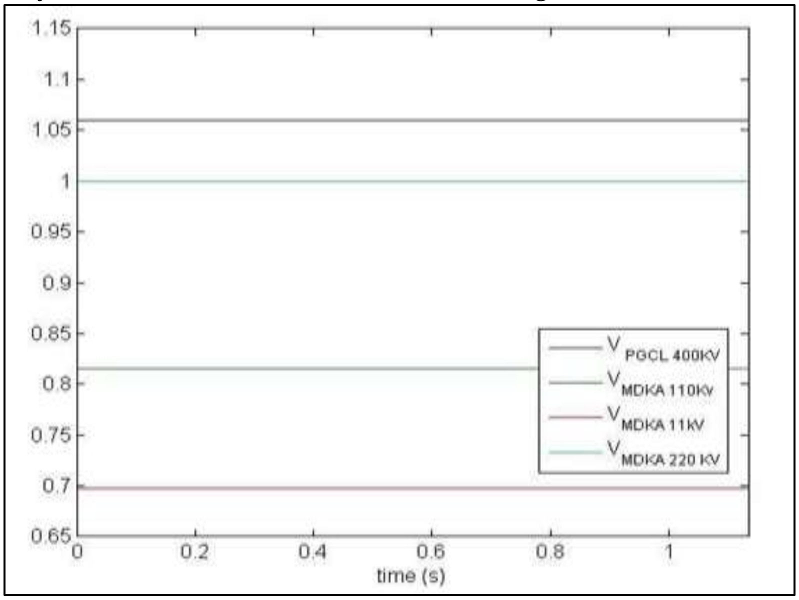

Fig. 6: Maximum Load Stability

C. Addition of Renewable Energy Resource

The wind energy is gaining attention among a variety of renewable energy resource mainly because it is a clean source of energy, renewable and also its running cost and maintenance is very less as compared to other energy sources. We are using Wind as Renewable source in this paper. The wind energy is fed into bus01.The figure 7 shows the addition of renewable source in

Madakkathara 400kV substation. The table5 shows the voltage of each bus after integration of Wind energy. In 11 kV bus we added static condenser for better voltage stability at each bus and reduction of reactive power.

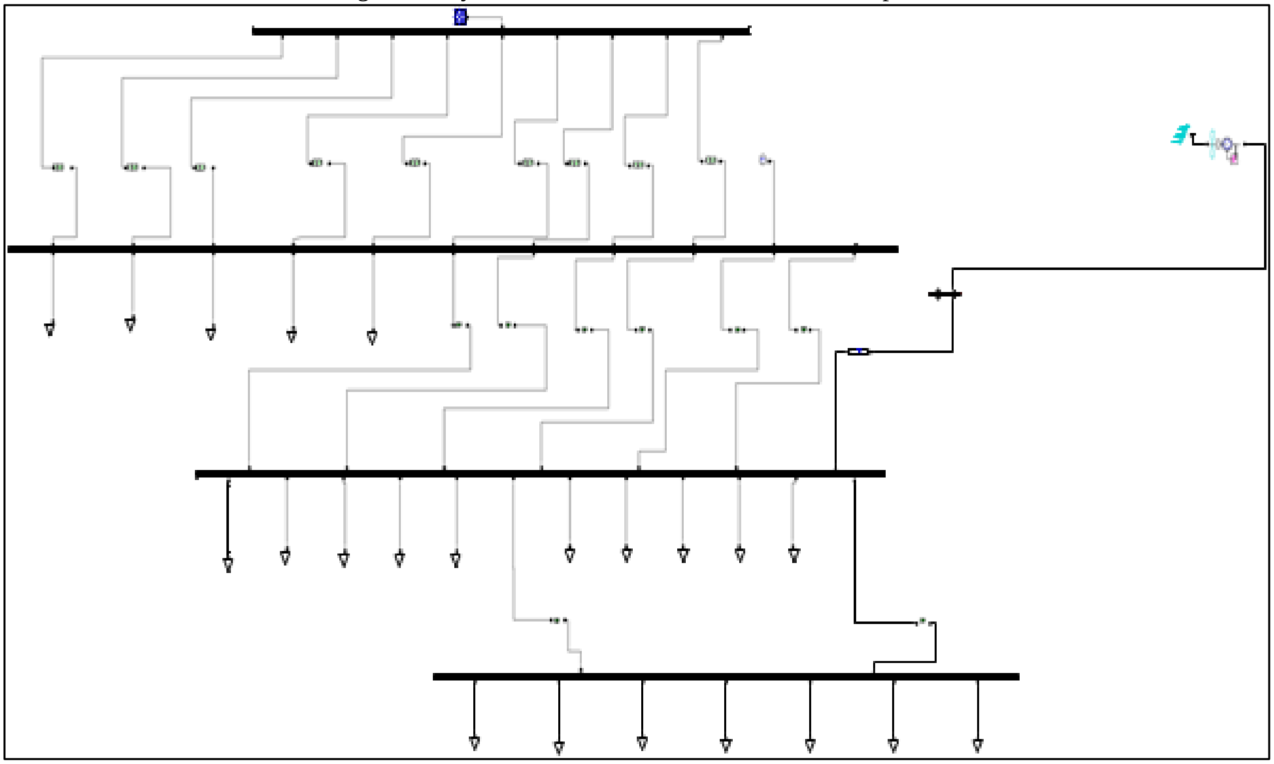

Fig. 7: Addition of renewable energy in Madakkathara substation

Table – 4
Maximum voltage after addition of renewable source in Madakkathara substation

BUSES	Vm(pu)
PGCL 400kv	1.06
BUS NO .01	0.96714
MDKA 110 KV	0.96709
MDKA 11KV	0.9341
MDKA 220 KV	0.1

The table 4 shows that busno.1 has got maximum voltage of 0.98503p .u due to the addition of wind farm to it. Through busno.1 we can expand Madakkathara substation by connecting different loads.

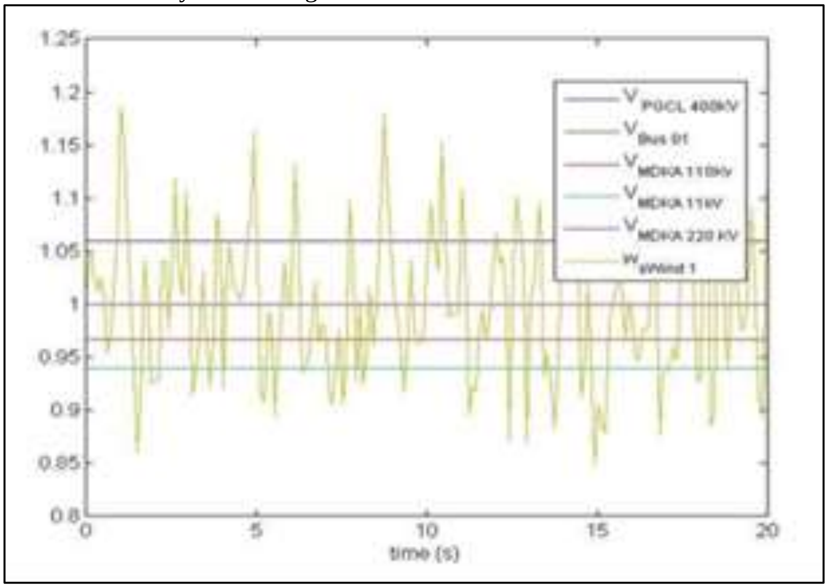

Fig. 8: Bus voltage with wind speed

IV. CONCLUSION AND FUTURE SCOPE

In this paper we present Voltage Stability analysis using PSAT. The main information obtained from the power-flow analysis are the real and reactive power flowing in each line, magnitude and phase angle of the voltage at each bus. Also, we analysed transient stability and maximum load stability of Madakkathara 400kV substation. We expand Madakkathara 400kV substation by adding wind farm. The high reactive power values need to be compensated using either the conventional compensators such as reactors, capacitor banks, and tap changing transformers or the use of FACTS devices.

It is important for planning future expansion of power systems as well as in determining the best operation of existing systems without any losses.

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