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Integration of Stability Model of PV System by Using WEEC Model and Generic Type 4 PV Model in PSSE Software

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Abstract—When a huge generation of power is generating from the solar power plant to the grid interconnection, the system tends to create a stability problem and thus disrupted the grid system in disturbance issues such as bus fault, line fault and tripping. This sudden disturbance and irradiance drop occurrence is tended to interrupt the stability of the system from providing balance electrical production within the electrical grid. The level of photovoltaic (PV) penetration also influences the constancy of the system longer duration critical clearing time (CCT) of the system fault occurrence back to its normal condition. This paper presents the development of PV plant model for dynamic stability assessment using the Siemens Power System Simulation for Engineering (PSSE) software. A dynamics response from simulation is used to investigate the stability and behaviour of PV plants in grid interconnection by constructing a 30-bus system in the PSSE using two types of PV generators and observe the system's behaviour where it reaches its stability.

Index Terms*—Stability, photovoltaic, *PSSE, renewable energy, PV plant, PV modelling

I. INTRODUCTION

IN these few decades renewable energy has been chosen in order to reduce the consumption of the fossil fuels which the main cause of environmental pollution which is climate change, air pollution, acid rain and global warming. The life time of the oil, natural gas and coal can at least last for 50, 51 and 132 years respectively based of the consumption of the energy and the known reserve in 2018[1]. Wind and solar energy resource have widely expanded in usage in the world and gaining importance in power system generation, where solar energy become one of the most faster growing and expected the penetration levels exceed 30% in the future [2]

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80% reduce the price of the solar PV panel over the last 7 year, with the latest innovation in solar PV development and research in order to wider the development of the PV plant.

The solar PV generator have different characteristic where different from conventional generator. The different where can be observe from these two types of generators which is from the output, where the output of the conventional generator can be adjusted and control by the user, no major stability problem occur to the generator even run at the rate of the output power. However, in term of renewable energy generator, the output cannot be arbitrarily adjusted [3]. Where like PV generator depend on the irradiation which is one and only source from the sun, where the output can't be determined and control which will result in fluctuation of the electrical power output. Other expect that need to take is about the solar temperature of the solar panel, effect from varying of temperature is when temperature of the panel increases it will reduce the efficiency of the panel, output current increases exponentially while its voltage output is decreased linearly and affected to the stability of the system. A huge sudden drop of the irradiance will tend to interrupt the stability of the system.

When the is system increase in penetration of the PV generator, the system may be loss its stability which can interrupt the system operation and can cause outage. High PV penetration level can significantly effect the transient stability as well as the steady state due to different characteristic from resources conventional generator[4]. Random penetration without proper planning of the PV plant may lead to serious damage the grid where it effect the power flow of the system and also the efficiency of the system. In view of the growing significance of RES penetration and its effects on the stability of the electric power system, investigations of the impact of RES penetration on the individual power grid have been done [5-9].

This paper presents the comparative study between two different PV generator in dynamic stability assessment in the PSSE software in order to study the stability of the generation of PV plant to the grid. The PV generator has been tested in two different dynamic simulation connected to custom model of 30 bus system with two different PV generator which is Generic Type 4 Model PV and WECC generic model generator to determine which generator tend to be in stability faster in with different PV generation. The (CCT) critical clearing time has been observe for both generator throughout this study to identify both PV generator reach its stability. This paper organize as follows. In section II about different type of PV generator has been used through this study and a brief description for each generator.While, section III where the result that has been obtained and been discussed and section IV conclusions that can be obtained and conclude from this investigation.

II. System Modelling

A. WECC Model

Beside designing conventional generator PSS/E program is used to design and develop the renewable generator such as wind and PV generator model for simulation. Generic Renewable Generator Model developed by WECC aims to capture the key characteristics of solar plants with centralised control at the point of connection (PCC) to a transmission grid.. By selecting proper value in order to performed dynamic simulation the most important dynamic basic machine model such as generator controller (REGC_A), electrical control model (REEC_B) and plant control (REPC_A) must be taken account such as block diagram show bellow. These module does not include plant protection or inverter where the existing generator model can act as and be used to represent time delayed voltage and frequency setting protection setting. However this model cannot varied its irradiance level where the irradiance level fix to 1000 W/m2.

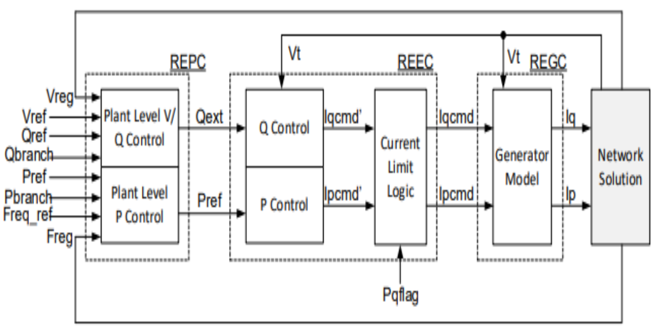

Fig. 1. Overall Model Structure for Central Station PV System WEEC Model

Renewable Energy Generator Converter Model (REGC_) in figure 2 represents the generator that interfere with the grid system where its processes the real and reactive current command and outputs of real and reactive current injection into the grid module. This model consists of current injection where the model will incorporate with a high bandwidth current regulator that inject real and reactive components of inverter into the external network solution in respond to the real and reactive current command [10].For protective function a set of six or more definite time and frequency protective element were used to trip the generation represent by the model where of the elements shall have and independent user- settable pickup and time delay. There were external model providing the ability to trip the generation represent by the model which is that included in the PSSE were FRQDCA/FRQTPA and VTGDCA/VTGTPA.

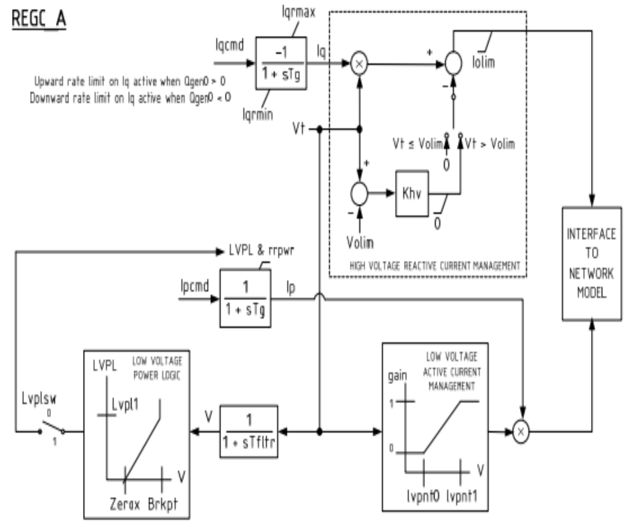

Fig. 2. REGC_A Model Block Diagram

Renewable Energy Electrical Controls Model (REEC_) in figure 3 used to present the electrical control to the inverter. It functions as on the reactive and active power reference from the REPC module with feedback of terminal voltage and generator power output, and gives real and reactive current commands to the REGC module. For local active power, the active power subsystem will provide [11] the active current command to the current injection module with feedback of generator power output and terminal voltage , and gives reactive and real current commands to the REGC module. For local reactive power, the local reactive power control will provide the reactive current command to the current injection model

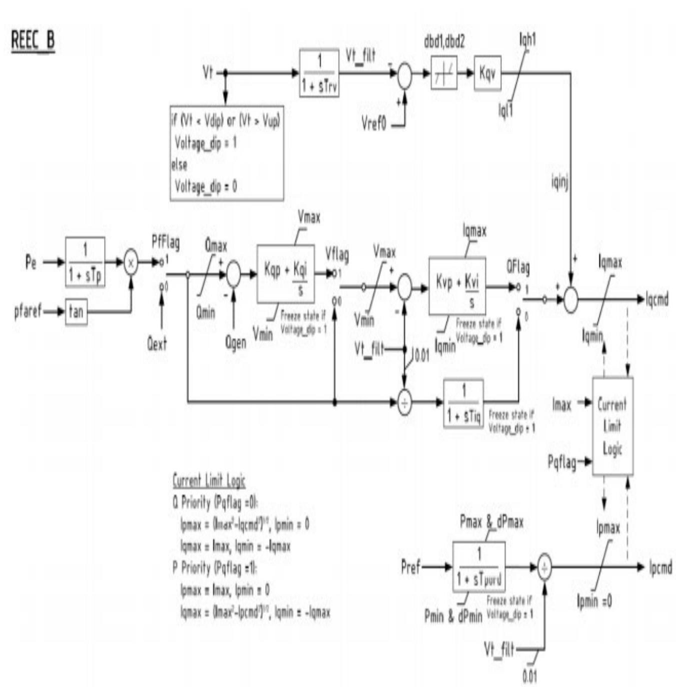

Fig. 3. REEC_B Model Block Diagram

Renewable Energy Plant Controller (REPC_) represents figure 4 below plant controller to the system it is an optional model used when active and reactive power is needed to the system, where its process voltage and reactive power output to emulate volt/Var control of the plant level and it also process active power output and frequency to imitate the active power control. This model supply active and reactive power to the REEC module. The voltage at the connection point or at another point in the grid that compensated by current were control by reactive power control [12]. Active power regulation, which includes primary frequency response based on a proportional regulator with dead band and ramp up and down limits, regulates the active power provided by the plant in a branch. This model is only available for grid codes that use an aggregated inverter model to represent PV plants.

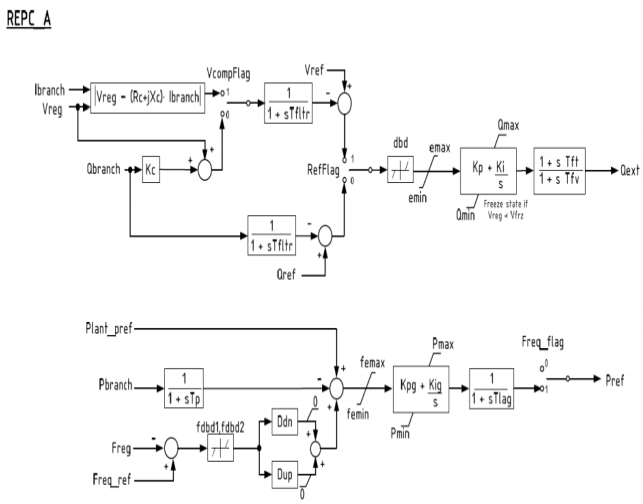

Fig.4. REPC_A Model Block Diagram

B. *Generic Type 4 Model PV*

PVGU represents the generator/converter module, PVEU represents the electrical control module, PANEL represents the mechanical module, and IRRAD represents the pitch module.. The PV system dynamic model in PSS/E is designed to replicate the performance of a PV plant connected to the grid via a power electronics-based conversion system, as shown in Fig. 5.

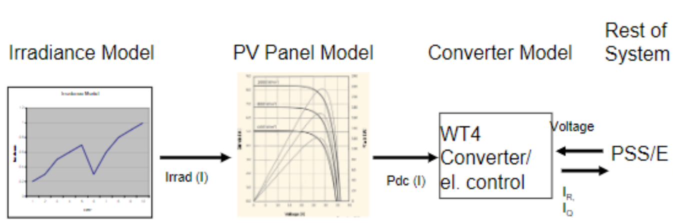

Fig. 5. PSSE PV model

For the irradiance model where that allow to varied the irradiance level in order to imitate the actual irradiance where when the the weather were cloudy or in raining day which the level of the irradiance were low where the irradiance can be varied from 0 W/m2 to more than 1000 W/m2.It is Initializes based on steady state P/Pmax. For each time step the outputs linearized with the irradiance level. The irradiance value is then supplied to the PANEL module, which uses I-V curves from PV manufacturers to calculate the DC power from the PV plant at the appropriate irradiance level. PV panel's output varies with temperature , terminal voltage , irradiance which can be set by MPPT.

Based on filtered active and reactive power directives from the electrical control module, the converter module (PVGU) calculates the current injection to the grid (PVEU). Under high/low voltage situations, both components of the injected current are processed using the specific logic diagram illustrated in figure 6, which is re-produced and altered from [13]. PVGU has two current regulators built in to simulate filtered active and reactive power commands before the grid injection point.

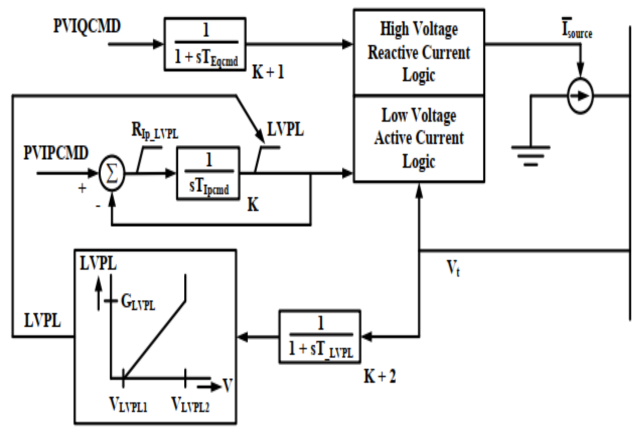

Fig. 6. PVGU model

The accompanying control system is the most important part of the converter-based conversion system. Figure 7 depicts the electrical control module for the PV generating system (PVEU) in PSS/E. To achieve varied regulatory objectives, the control system consists of decoupled active and reactive power control logic. Using decoupled active and reactive power control, the PVEU creates the reactive power current command and the active power current command.

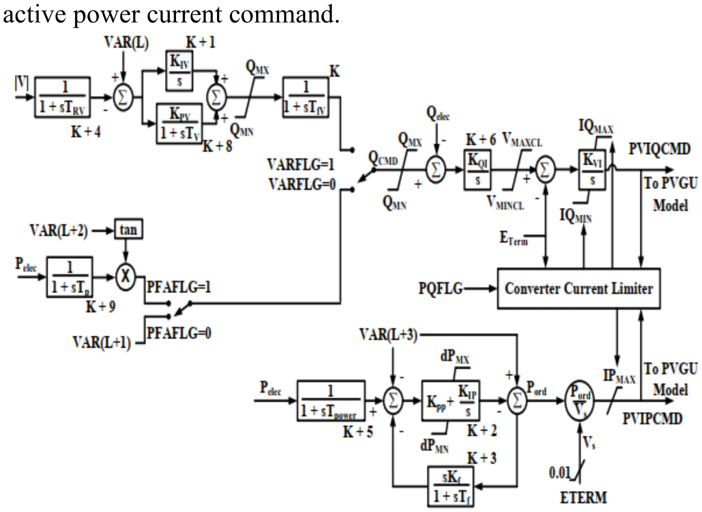

Fig. 7. PVEU MODEL

III. Result

In this study the modeled bus system consists of 30 bus , 10 loads, 2 conventional generator and 2 renewable generator as shown in figure 8 were subjected by disturbance which is fault during dynamic simulation and the behavior of the system will be observe either its stable where the system back to its normal condition or not.The modeled bus system will go through several dynamic simulation where the renewable generator used generic Type 4 Model PV generator and WECC generator separately. The system has been subjected with fault in 0.1 second of duration. Even its in short amount of time fault been applied some of the previous study show that the system become unstable and did not back to its normal condition.

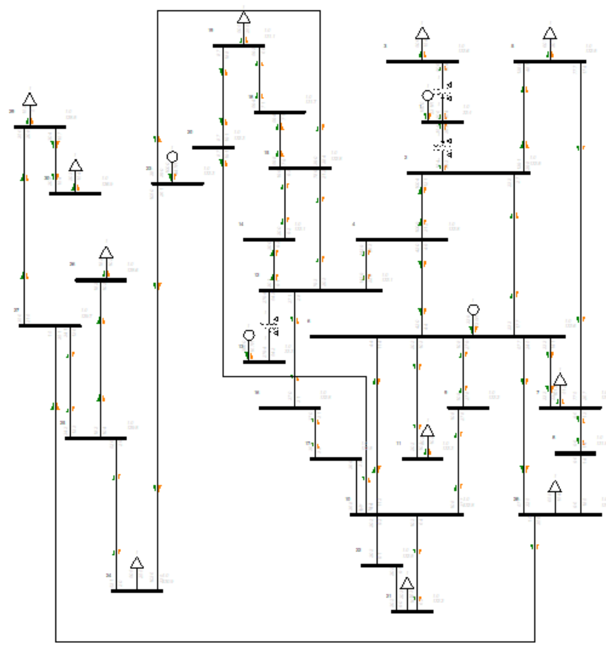

Fig. 8. 30 bus system

The performed dynamic simulation examines the immediate response after fault and tripping condition and inspect the CCT.CCT is defined as the maximum time during which disturbance can occur without having losing its stability, the higher the generation of the PV generator the longer the time and the higher the magnitude the system oscillated until back to its normal condition.For the model generic Type 4 Model PV generator the simulation has been done with 2 different scenario where the irradince will be fixed and the other scenario is the irradiance will drop from 1000 W/m2 to 0 W/m2

A. WECC Model

Figure 9 and 10 illustrate the active and reactive power respond of the all PV generator output during the fault has been applied at bus 1 and bus 23. For the active power, the result that has been obtain show that all the PV generator oscillated at the same time start at t= 1s and oscillated until t=1.5 s and after that the system back to its normal condition where its show the system is stable, where the result show that the active power drop to zero and remain zero until the fault has been cleared at t=1.1s .The magnitude of the oscillation were different where its show that the different in generation level between the PV generator. For the reactive power also show that the level of penetration level influence the magnitude of the oscillation of the system. The reactive power output oscillates at t=1s where the fault has been applied and oscillated back to its normal condition where at its steady state pre- fault value when the fault has been cleared at t = 1.1s and take about t= 8s where its oscillated back to its normal condition in order to regain its stability.

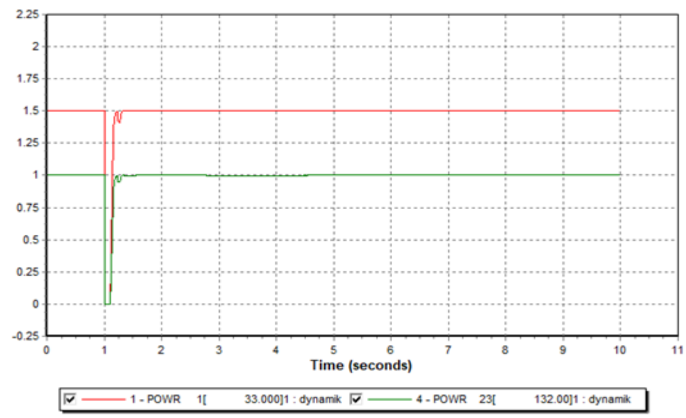

Fig. 9. Active power output

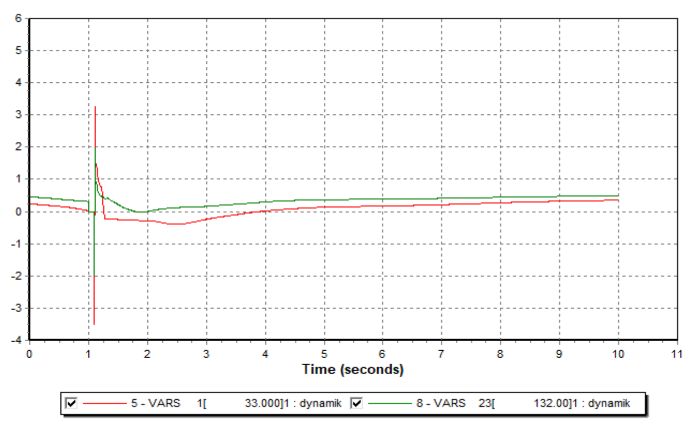

Fig. 10. Reactive power output

Figure 9 © show that the result for the voltage profile. It is revealed from the simulation result the fault has been applied at t= 1s all the PV generator of the bus voltage drop to zero value and remain zero until the fault has been cleared at t = 1.1s.The bus voltage undergoes few oscillation just after the fault has been cleared and settle down to pre-fault level after near to t = 4s as observe in figure 8©, the magnitude of the oscillation behavior show the same as the previous active and reactive output where the higher PV generation the higher the magnitude of the oscillation which may affect the voltage stability of the system in absence of optimum solution to protect the system from unwanted condition.

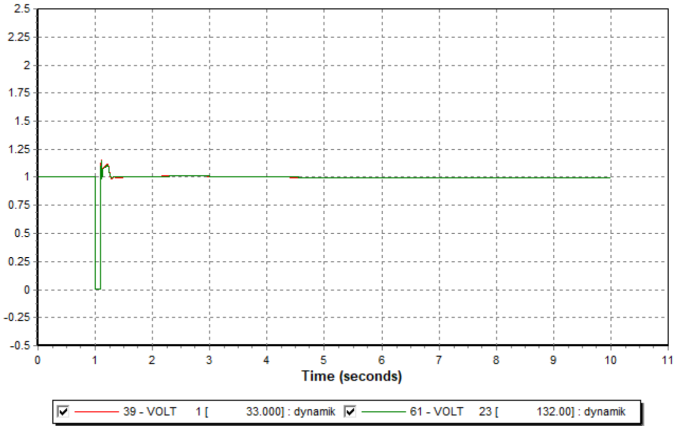

Fig. 11. Voltage profile

Figure 8 (d) show the impact of the fault to the frequency response of the system where the fault has been stimulated at the PV connected to the system. Under the simulated fault scenario, the fault has been applied at t=1s where the result show that the frequency respond oscillated with different level of magnitude due to the different level of PV generation. When the fault has been cleared at t=1.1s the magnitude of the frequency start to settle down and regain its stability where the frequency back to its normal condition and take about t = 2.5 s where it's show that the system is stable to all the PV generator installed in the system .The variation in the magnitude of the oscillation may lead to triggering of series of load shedding relay where these procedures describe the activities performed by an operator after the load shedding by frequency opened a corresponding set of circuit breaker which loads being disconnected from the power system and when the emergency situation is over the operation restore its power.The above nature of frequency respond demands significant thrust in the area of protection co-ordination for the reliable system operation.

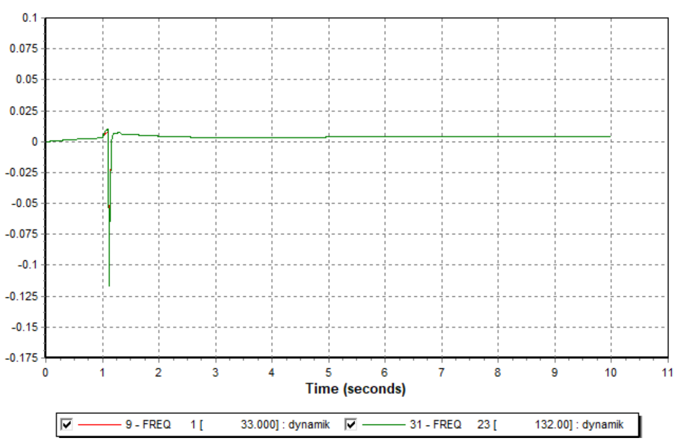

Fig. 12. Frequency deviation output

B. Type 4 Model PV generator

In figure 13(a) show that the fault has been injected at t=1.1s where the duration fault of the fault is about 100 ms and the output show that the active power drop to zero and keep fluctuate to gain its stability where at t=3.3 the output result show that the system gain its stability. The level of oscillation is also different this is because of the different level of penetration. The conventional generator produces a part of lost PV generation and its total generation increase, some part of the lost PV generation must be delivered to the system in order to maintain the stability of the system.The duration of the system gain its stability is around t=2.2 second.While in figure 13(b) show that where the sudden irradiance drop from 1000 W/m2 to 0 W/m2 at t=1s and varied back 1000 W/m2 where the simulation result show that the output drop to zero and keep fluctuate until regains its stability where the duration for the system of the system to get back to its normal condition is less that when the PV generator been injected by fault where the duration is about t= 2s.From the result observed show that the PV that has higher generation tend to have higher magnitude of oscillation, where the higher the the generation the longer take time for the system to get back to its normal condition

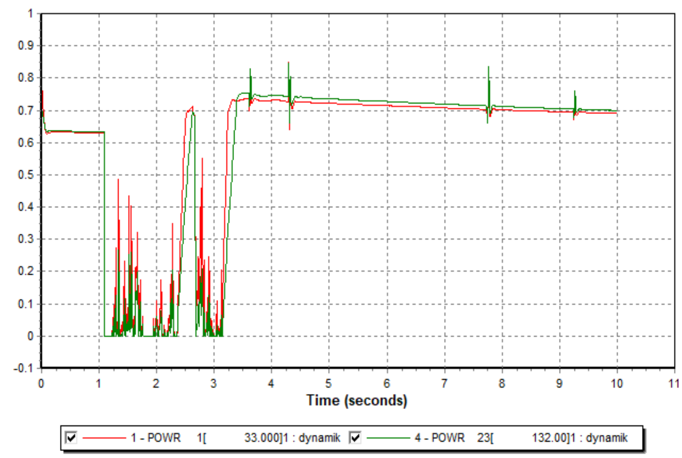

Fig. 13(a). Active power output

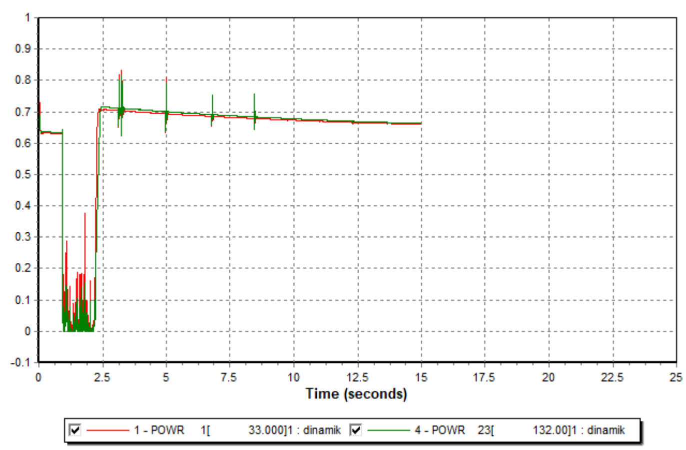

Fig. 13(b). Active power output (irradiation drop)

Figure 14(a) show the result of the voltage profile of the bus at the PV has been connected. From the figure below show that the tripping occurs at t = 1.1s where its show that huge drop of after been subjected by fault and oscillated back to its normal condition where its show the system is stable where take around t= 2.3s to get back at its initial condition. A fault occur creates a momentary oscillation for the voltage profile. From the result show the magnitude of the oscillation is different where it shows that the higher penetration oscillated higher oscillation which show that the effect of the level of penetration that penetrate through the system where the at bus 1 has higher penetration level than bus 23. The higher the penetration, the higher the magnitude of oscillation.Figure 14(b) state that when the irradiance has been drop to zero at t= 1s the output result show fluctuation in in oscillation where at t= 6s the system back to its normal condition where show that the system is stable.Both output result show the same behavior where reach its stability before t=10s but different in time taken before get back to its normal condition.

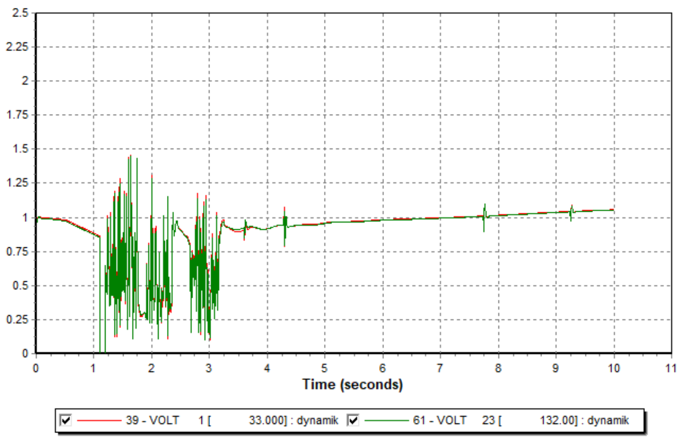

Fig. 14(a). Voltage profile

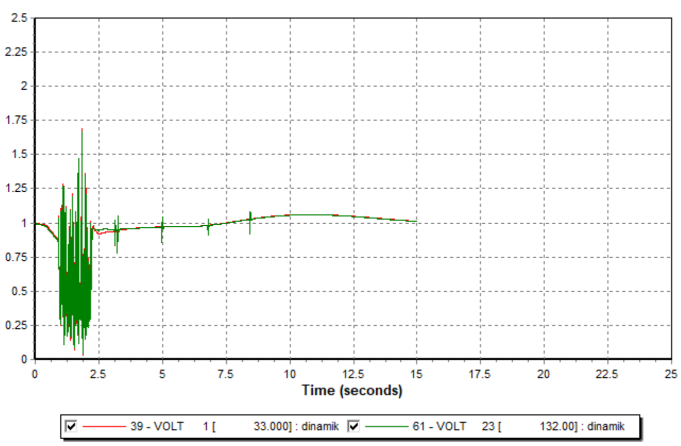

Fig. 14(b). Voltage profile (irradiation drop)

Figure 15(a) show the result of output power after the PV generator has been applied fault. The result show that the behavior of PV generator where the PV generator drop to zero at t= 1.1s this is because the PV generator has been tripped and the conventional generator oscillated and back to its normal condition in between t=3.2s where it show the system is stable. The level of oscillation is also different this is because of the different level of penetration. The conventional generator produces a part of lost PV generation and its total generation increase, some part of the lost PV generation must be delivered to the system in order to maintain the stability of the system. So, the maximum PV integration limit should be optimized in a way that the sudden tripping of large PV plant does not lead to damage the system by the conventional generating unit in the system in order to avoid overloading limits of power system.While figure 15(b) where the irradiance drop at t=1s show that the magnitude output of the system oscillated the same way with the fault simulation where its oscillated reach 0.5 which is higher than the fault simulation.The system take around 1.5s to settle back to take its stability at t=2.8s.Both result oscillated identically but take different time to settled down and become stable.

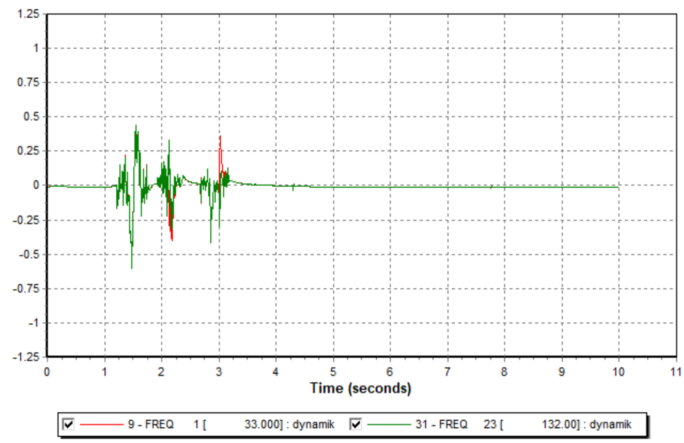

Fig. 15. Frequency deviation output

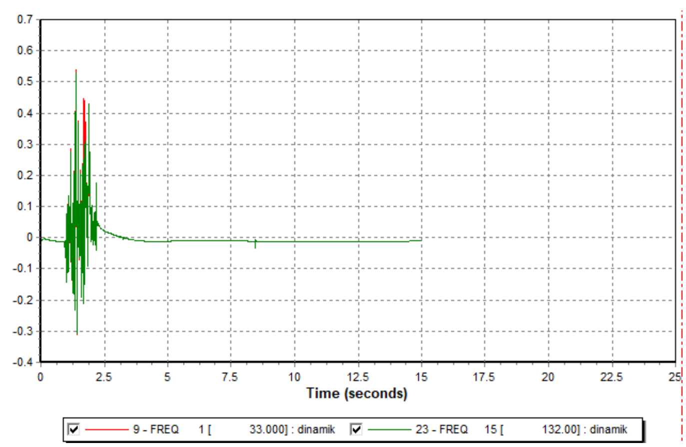

Fig. 15. Frequency deviation output (irradiation drop)

IV. Conclusion

This study give a clear view of PV plant interconnection to the grid where the behavior of the PV plant system can be observed with different generation level and also the sudden drop of irradiance of PV generator effect the stability of the system. A custom 30 bus system with using user models to generic models as the ones proposed WEEC and Type 4 Model PV generator for dynamic model of a PV plant was build. However the WECC model cant varied it's irradiation, but in term of the stability the WECC model tend to have better time taken for the system to be stable then Type 4 Model PV generator. It was found that with large PV plant, the system more vulnerable to stability problem. From the simulation result show that for the Type 4 Model PV generator during dynamic simulation show that for the irradiance drop the system tend to have faster time to achieve stability then fault apply to the generator in fixed irradiance. The dynamic respond of active power delivered by the PV plant is faster than the conventional generator to achieve a stable state after post fault. Overall from the simulation result it is safe to say that the PV plant in the system stable due to fault and sudden irradiance for high PV generation which is both generate more than 100M Watt. Beside that the study found out that the different level of generation will cause the higher magnitude of oscillation and take longer time to settle down and the sudden drop of irradiance can lead to the system become unstable and tend damage the generator if not design properly.

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REFERENCES

[1] J. L. Holechek, H. M. E. Geli, and M. N. Sawalhah, “A Global Assessment : Can Renewable Energy Replace Fossil Fuels by 2050 ?,” pp. 1–22, 2022

[2] D. Remon, A. M. Cantarellas, J. M. Mauricio and P. Rodriguez, "Power system stability analysis under increasing penetration of photovoltaic power plants with synchronous power controllers," in *IET Renewable Power Generation*, vol. 11, no. 6, pp. 733-741, 2017 USA: Abbrev. of Publisher, year, ch.*x*, sec. *x*, pp. *xxx–xxx*

[3] S. Oh, H. Shin, H. Cho, and B. Lee, “Transient impact analysis of high renewable energy sources penetration according to the future Korean power grid scenario,” *Sustain.*, vol. 10, no. 11, 2018, doi: 10.3390/su10114140.

[4] K. Emmanuel, T. Antonis, Y. Katsigiannis, and M. Moschakis, “Impact of increased RES generation on power systems dynamic performance,” *Mater. Sci. Forum*, vol. 721, pp. 185–190, 2012, doi: 10.4028/www.scientific.net/MSF.721.185.

[5] Siemens PTI Study Team. PREPA Renewable Generation Integration Study. Available online: https://www. aeepr.com/Docs/Siemens%20PTI%20Final%20Report%20-%20PREPA%20Renewable%20-%20final-11.pdf (accessed on 23 MAY 2021).

[6] Tamimi, B.; Cañizares, C.; Bhattacharya, K. System stability impact of large-scale and distributed solar photovoltaic generation: The case of Ontario, Canada. *IEEE Trans. Sustain. Energy* 2013, *4*, 680–688

[7] TransGrid, New South Wales Transmission Annual Planning Report 2017. Available online: https://www.transgrid.com.au/news-views/publications/transmission-annual-planning-report/Documents/Transmission%20Annual%20Planning%20Report%202017.pdf (accessed on 23 FEB 2021).

[8] EirGrid. *All Island TSO Facilitation of Renewable Studies*; EirGrid: Dublin, Ireland, 2010

[9] Rodriguez, R.A.; Becker, S.; Andresen, G.B.; Heide, D.; Greiner, M. Transmission needs across a fully renewable European power system . *Renew. Energy* 2014, *63*, 467–476

[10] WECC Renewable Energy Modeling Task Force, WECC Wind Power Plant Dynamic Modelling Guide, September 2014..Available online: http://www.wecc.biz(accessed on 5 MAY 2021).

[11] WECC, Solar Photovoltaic Power Plant Modeling and Validation Guideline, DEC 2019. Available online:https://www.wecc.org/Reliability/Solar%20PV%20Plant%20Modeling%20and%20Validation%20Guidline.pdf (accessed on 15 MAY 2021).

[12] WECC, WECC White Paper on Converting REEC_B to REEC_A For Solar Pv Generators, JUNE 2019. Available online : https://docplayer.net/153534982-Wecc-white-paper-on-converting-reec_b-to-reec_a-for-solar-pv-generators.html (accessed on 10 MAY 2021).

[13] *Siemens PTI, PSS/E Program Operation Manual, Version 33.4, 2013 release*, 2013