ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Enhancement of Small Signal Stability in Power Systems by Using ECS Together With Wind Unit

Esampalli Anil
M.Tech(E.P.S),
Arjun College of Technology and Sciences.

G.Ganesh, M.Tech (P.E)
Assistant Professor
Arjun College of Technology and Sciences.

Abstract

A study of small signal stability of power systems including wind units and energy capacitor systems (ECSs) in terms of frequency as a function of time is presented in this paper. Modeling of wind units with squirrel-cage induction generators connected to power system through a full-scale AC/AC converter and ECS unit are explained t. The ECS unit consists of electric double-layer capacitors (EDLC) and DC/AC converter. Small signal stability of 3 test systems are studied and compared with one another using mat lab simulations. The three systems are: S1) WSCC 9-bus system with three conventional synchronous generators (SGs), S2) the WSCC 9-bus system with one of the conventional SGs replaced by a wind unit and S3) the same as S2 but with the addition of an ECS unit. The study includes the effects of loading on the unstable modes of the system with conventional SG, wind and ECS units are studied using the mat lab simulations as loads are increased.

I.INTRODUCTION

Cheapest and cleanest sources of all among electrical energy is wind energy.In the world,198 GW of wind capacity Installed up to the year of 2010 by invested 50$ billion on wind energy in last twenty years Increased installation of wind energy in power system produces deteriorated system dynamics due to nature of wind speed To compensate for these deteriorations new methods and equipment should be employed.

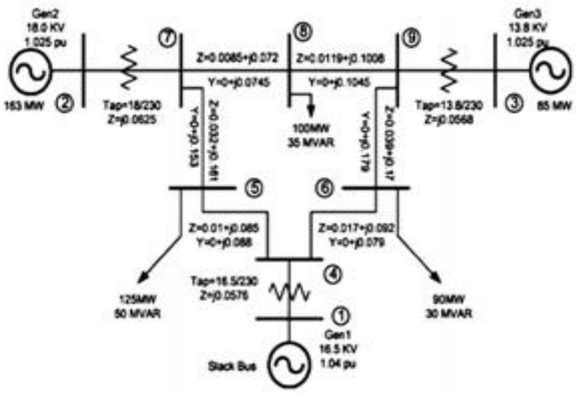

Figure-1: WSCC 9-bus system

II.MODELING OF SYSTEM

For synchronous generator one axis model is used. This model assumes one-mass steam turbine, each generator is assumed to be equipped with an IEEE DC-1A type exciter

a)WIND UNIT: For wind unit, a squirrel-cage induction generator (SCIG) connected to the grid through a full-scale AC/AC converter (a combination of generator side AC/DC and grid side DC/AC converters) is used. Wind unit speed is modeled and it shown in below figure.

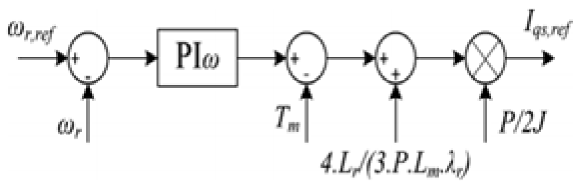

Fig-2: Block diagram of rotor speed control loop.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Dynamic equations of SCIG and the related converters are as follows

$$sW_r = \frac{P}{2J}(T_m + T_e)$$

$$sI_{qs} = \frac{1}{L_\sigma}\left(\frac{1}{2}m_{qs}V_{dc} - RI_{qs} - w_e L_\sigma I_{ds} - \frac{w_r L_m \lambda_r}{L_r}\right)$$

For generator side converter, the control objectives are related to maximum power point tracking (MPPT) and indirect filed-orientation control. Based on these strategies block diagrams of rotor speed control loop (to achieve maximum power point) and generator-side current control loops are designed as Figs. 2 and 3, respectively.

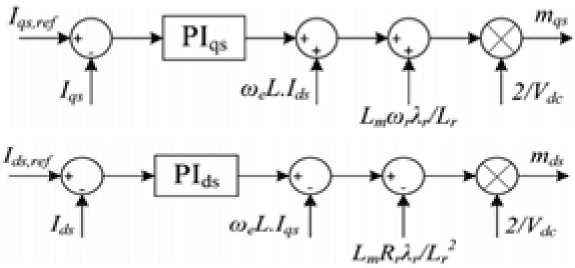

Fig-3: Block diagram of the generator-side control loops.

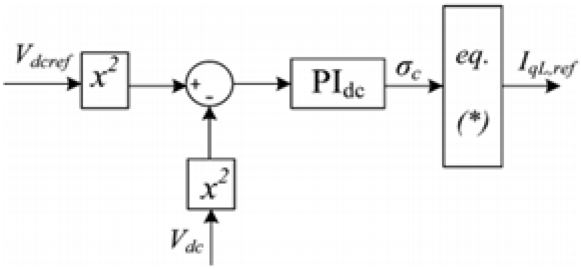

Fig-4: Block diagram of the DC-link voltage controller.

For grid side converter, the control objectives are to maintain constant DC-link voltage and regulate the output reactive power of the wind unit. Fig. 4 shows block diagram of the DC-link voltage controller, and Fig. 5 shows block diagrams of the grid side converter control loops. Equation (*) in Fig. 4 is defined as follows:

$$I_{qL,ref} = \frac{2}{3V_{qg}}(\sigma_c - P_{in} - P_{loss})$$

b)ECS UNIT: Below figure-5 shows the schematic diagram of an ECS unit. The control objectives for this unit are to regulate the output active and reactive powers of the unit through controlling the q- and d-axis components of the ECS output current (Iqe and Ide),current control loops are shown in Figure-6.

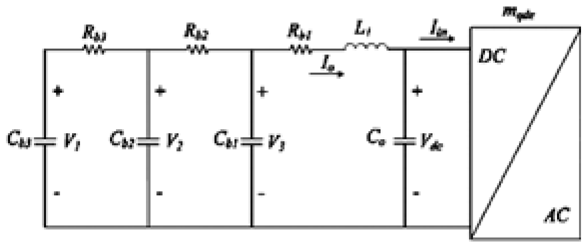

Fig-5: Block diagram of an ECS (EDLC) unit.

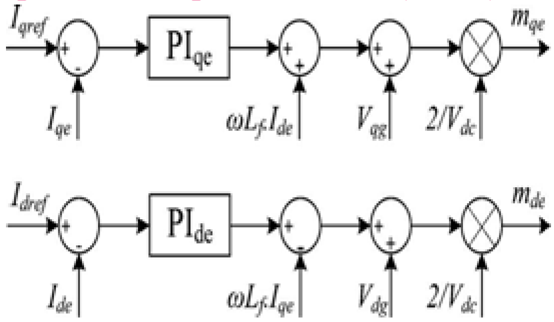

Fig-6: Block diagram of current control loops of ECS

$$P_{ref} = \frac{3}{2}|V_g|I_{q,ref}$$

$$Q_{ref} = -\frac{3}{2}|V_g|I_{d,ref}$$

For studying the effects of wind and ECS units on the steady state characteristics of overall power system. we consider a wind unit together with an ECS unit connected to a grid.

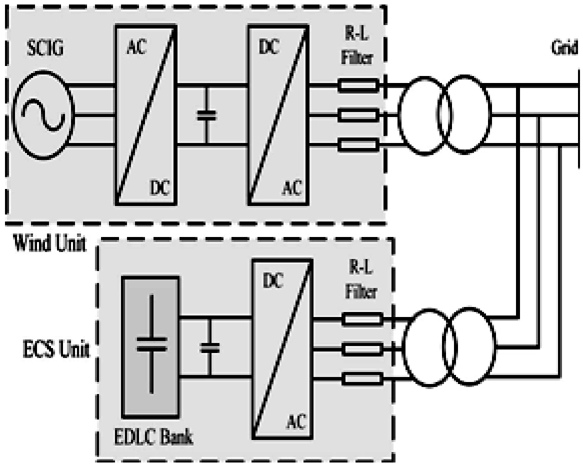

Fig-7: ECS unit together with wind unit

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

III.CASE STUDY

For investigating the small signal stability of a power system including wind and ECS units, Western System Coordinating Council(WSCC) is used. This system has 3 generators, three 2 winding transformers, 6 lines and 3 loads as shown in the figure of WSCC 9-bus system.

From the figure-8 the frequency of synchronous generator at bus1 for 3 test systems for a step change(increase) in load at bus5. Comparing the steady state values of three systems ,it can be seen that the system with wind unit(S2) experiences more frequency reduction than the system with all synchronous generators(S1).
The figure also shows that,when the ECS unit is added(S3),The steady state error is almost zero.This is due to fact that the ECS unit acts as fast governor and supports added load.It should be noted that the effectiveness of ECS is for a short period of time since ECS cannot support the added load for more than a few minutes.It is reasonable to assume that the governors of the remaining synchronous generators will compensate for the load change for long time.

To study the un-stable modes of each test system,the load at bus-5 and generation of all generators(including wind unit) are increased until the system becomes un-stable

IV.ANALYSIVS OF SIMULATION RESULTS

Simulation results of three different test systems are compared. Those are,

S1: The original WSCC system with three conventional synchronous generators.

S2: Synchronous generator at Bus 2 is replaced with a wind unit

S3: Synchronous generator at Bus 2 is replaced with a combined wind and ECS units.

As loads and generations are increased instability appears in all 3 systems

a) Load ability of the system decreases when a synchronous generator is replaced by wind unit. Hence it should be noted that loading ability of S2 is less compared to S1.

b) ECS unit can increase the load ability of the system. The load ability of a system (i.e.S3) with combined wind and ECS is even larger than a system without wind unit (i.e.S1).

From figure-8, Comparing the frequency as a function of time of the three systems it can be seen that the system with wind unit (S2) experiences frequency reduction more than the system with all exciting generator (S1).

Therefore ,in case of a system with only synchronous generator and ECS unit,load ability is higher than ECS with wind unit (S3)

V.SIMULINK DIAGRAMS AND OUTPUT RESULTS

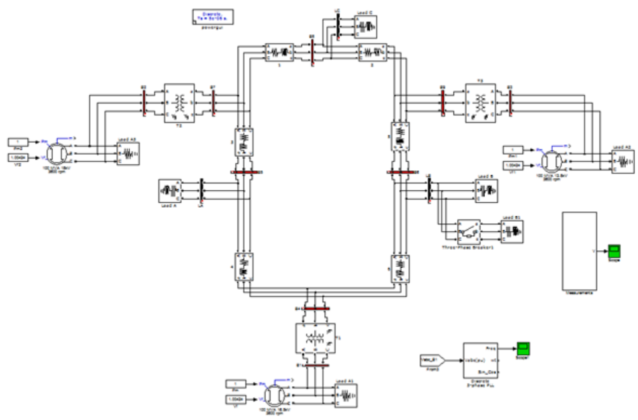

Fig-S1: WSCC 9-Bus system with 3 Synchrous generators.

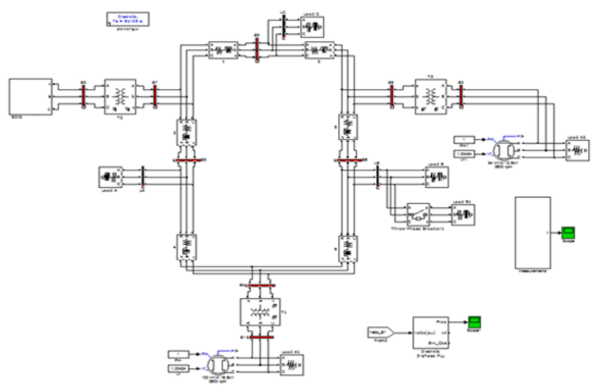

Fig-S2: WSCC 9-Bus system with first Synchrous generator is replaced with Wind unit

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

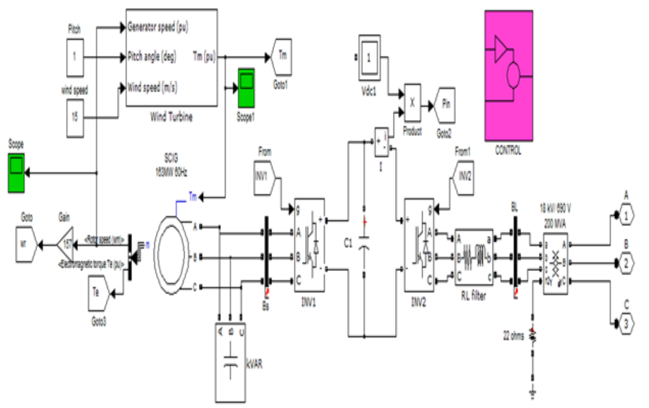

Figure: Internal diagram of the wind unit

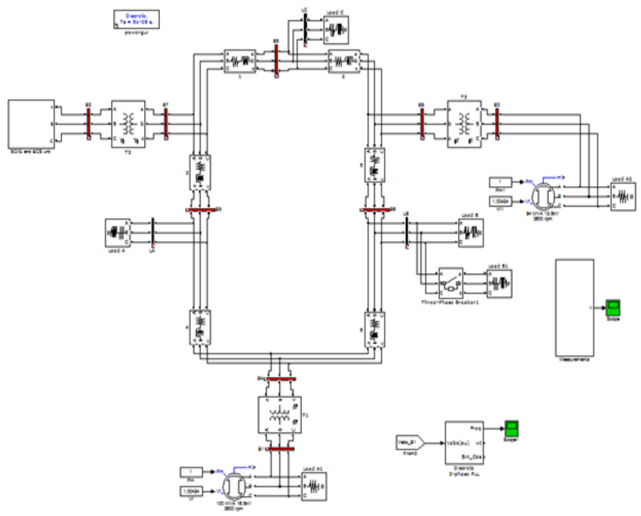

Fig-S3: WSCC 9 Bus system with first Synchrous generator is replaced with ECS together WIND unit.

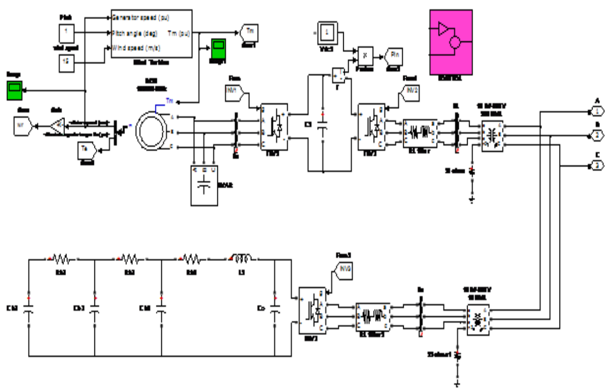

Figure: Internal diagram of the wind unit with ECS unit (EDLC).

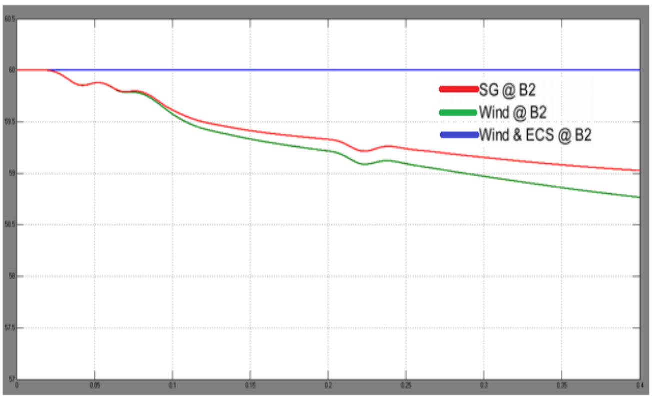

Fig-8: Comparing the frequency of synchronous generator at Bus-1 to the load change at Bus-5

VI.CONCLUSION

Small signal stability of a power system including wind and ECS units was compared with two other systems

a) While replacing a synchronous machine with a wind unit has negative effect on load ability of the system,

b) Addition of ECS unit can increase the load ability.The increased load ability is even more than the original system having synchronous generators only.

c)From the simulation results it was found that wind units (in a system without ECS) do not participate at unstable modes of the system, but after adding ECS unit to the system both ECS and wind units cause unstable values.

It can be concluded that adding ECS can also enhance the stability and/or load ability of the overall system.

REFERENCES

[1] International Energy Statistics EIA's Portal for Detailed Country and Regional Energy Data [Online].

[2] Huang wei ,Wang xin ” Discussion on application of super capacitor energy storage system in microgrid”

[3]W.Z.chen, Q.B.li “Energy storage sizing for dispatchability of wind farm”

[4] S. Teleke, M. E. Baran, S. Bhattacharya, and A. Q. Huang, “Optimalcontrol of battery energy storage for wind farm dispatching,”

[5] S. M. Muyeen, T. Murata, and J. Tamura, "Stability Augmentation of a Grid-Connected Wind Farm".

[6] P. W. Sauer and M. A. Pai," Power System Dynamics and Stability"

[7] IEEE Recommended Practice for "Excitation System Models for Power System Stability Studies"

[8] P. M. Anderson and A. Bose, "Stability simulation of wind turbinesystems,"

[9] A. Jamehbozorg and G. Radman, "Enhancement of micro-grid dynamics in presence of wind units using energy capacitor systems,"

[10] W. Bin, L. Yongqiang, and K. Samir, "Power Conversion and Control of Wind Energy Systems"

[11]K A Folly, "Robust controller design for small signall stability enhancement of power systems" Dept of Elec cape town,south africa