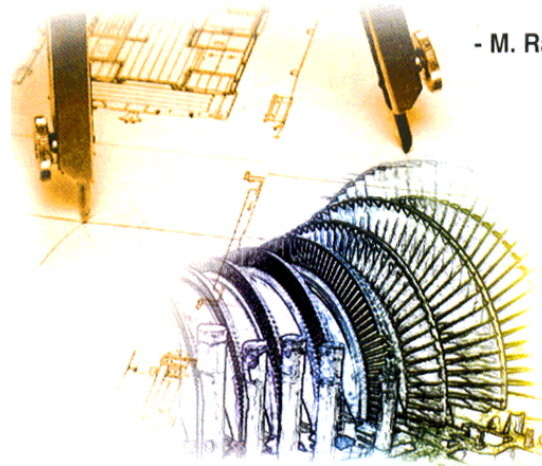


Capacity Increase of AC Turbo Generator by Redesigning

A C Generators either old or new, Indian or foreign make are in extensive use in our country. These generators are in use for exporting power to grid or for co-generation etc. In some of these generators, there exists an excellent opportunity for up-rating the capacity. Up-rating can be done by optimum utilization of electromagnetic materials and latest insulating materials.

Recently, by re-designing, we have increased the capacity of 7.7 MW AC generator to 9.0 MW. This project has been conceived and required by Bhagya Nagar Solvent Extraction Pvt. Ltd, Raichur, Karnataka. The generator was analyzed and the armature was rewound with new winding data. Rotor winding and exciter windings were not changed. The design aspects the performance are detailed in this article.



- M. Ramakrishna Rao

Considering at generator's thermal performance and increasing its capacity by overloading will increase armature copper loss, field current and field copper loss, exciter loss and also steady state load angle. In the present case, where the capacity increase is 16.88 % over 7.7 MW, the generator operating flux was increased. The field current, which is the result of increased no-load flux and new armature reaction, was compared with original field current. The resulting loss and temperature rise was checked for its limit. Accordingly, the new capacity was fixed.

Approach:

The generator nameplate information and OC characteristics (before up-rating) are given below

- A C Generator data: Voltage 11 KV
- Speed: 3000 RPM
- Freq: 50 Hz
- Output: 7.7 MW
- P F: 0.8
- MVA: 9.625
- Current: 505 Amps
- Efficiency: 97.6 %
- Type: Turbo Generator
- Make: Russian
- Class of Insulation of windings: of rotor F
of armature F

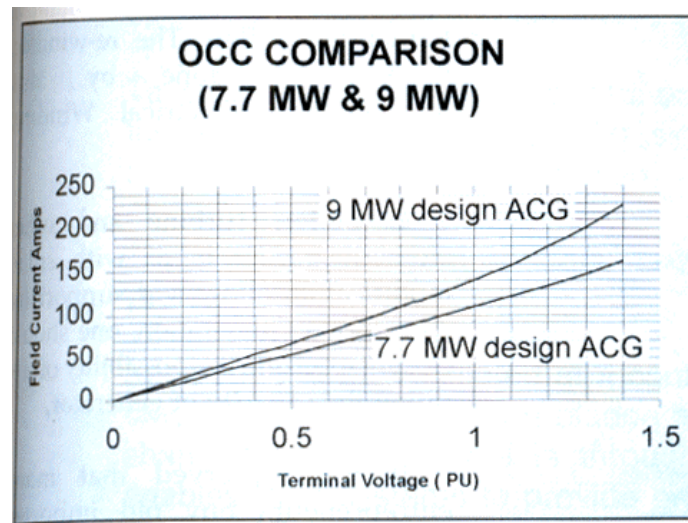
Armature Winding:

The turns per phase were reduced from 45 to 36 (a reduction of 20 % over 7.7 MW). The armature winding resistance has reduced from 0.048 to 0.032 ohms/phase cold @25 deg C. (at

7.7 MW is 505 Amps and the current for 9 MW is 590 Amps. Armature copper loss for 7.7 MW is 50.8 kW whereas for 9 MW is 45.32 kW. The armature copper loss has reduced by 10.7 % over 7.7 MW at higher output of 9 MW.

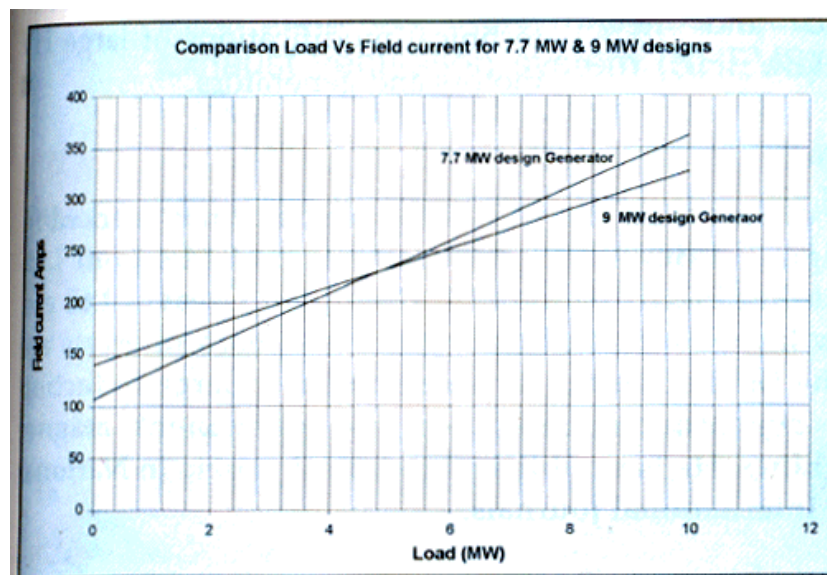
Open Circuit Characteristics

The OC field current has gone up from 106.8 to 169 amps, an approximate increase of 58.2 % over 7.7 MW. The iron loss will increase, but this new value could not be measured but estimated.



Field Current:

The field current, from no-load to full load, for both the ratings are shown in graph. It may be observed from the graph that at no load, the field current of 9 MW design is more by 59 % over 7.7 MW design, and the same is gradually reducing at higher loads. This is due to reduced armature reaction with new armature winding. At 9 MW the increase in field current is less than 5 % compared to 7.7 MW with armature old design. Since the increase in field current is marginal, the exciter windings were not changed.



Generator efficiency has gone up from 97.6 % to 97.79 %				
SI No	Loss	At 7.7 MW output	At 9 MW output	Remark
1	Armature Copper Loss KW	50.8 kW	45.32 kW	Reduction
2	Field Copper Loss KW	49.56 kW	54.64 kW	Reduction
3	Friction and Windage Loss	51.3 kW	51.3 kW	No change
4	Iron Loss KW (Estimated)	37.95	59 kW	Increased
5	Total Loss	189.3	210 kW	Increased
6	Efficiency%	97.6	97.71	Improved

AC Generator Loss & Efficiency:

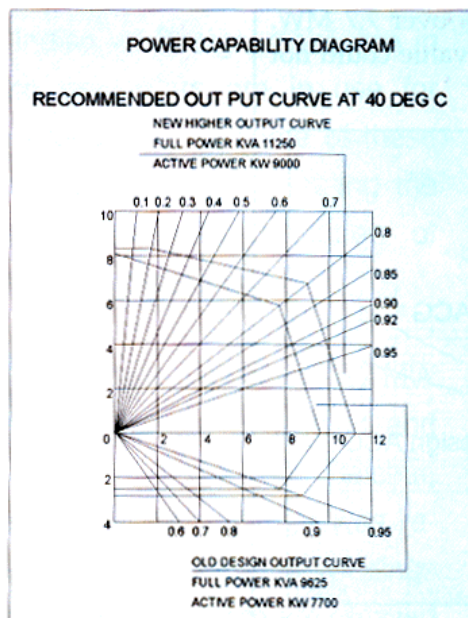
As mentioned earlier, the armature copper loss has reduced. The excitation loss has marginally gone up. Ventilation circuit is not changed and therefore, the friction and windage loss does not change.

Temperature rise:

The maximum winding temperature, measured by RTD is 76.1 Degrees C at 9.2 MW. This is within permissible temperature limits.

Load Angle and steady State Stability:

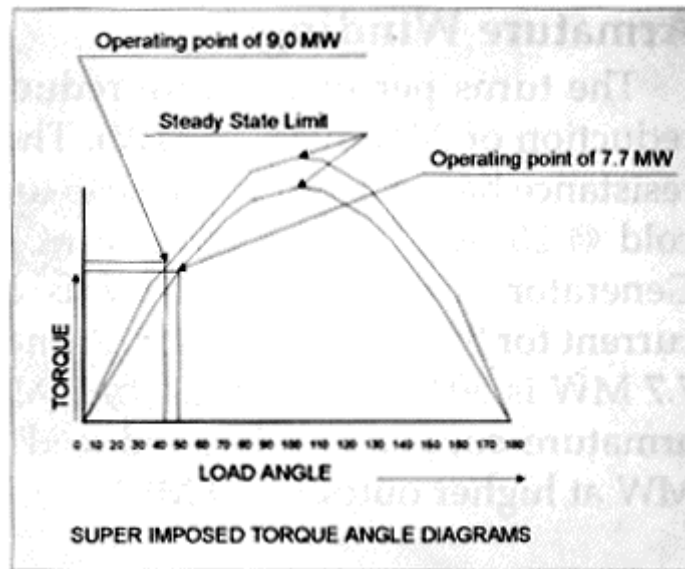
The load angle for 7.7 MW and at 0.8 PF is 39 deg and at UPF it is 69.1 deg. The load angle for 9 MW and at 0.8 PF is 32 deg and at UPF it is 62 deg.



Generator feeding power to grid, usually operate between 0.8 PF and 0.98 PF. From steady state stability point of view, the new load angle values mean, the operating point has shifted to a better value at 0.8 PF and UPF.

Power capability:

The power capability diagram of generator with old and new windings is shown below.



Conclusion:

The generator was successfully up-rated from 7.7 MW to 9 MW. The design and development work was done by the author and consultant M Ramakrishna Rao. The re-winding work was done by M/s Ramakrishna Electrical Winding Works, Kakinada.

If boiler, turbine and other elements, as it is or with small modification allow and support for more power generation, one should closely examine the possibility of up-rating the capacity of generator.

It was observed that many entrepreneurs buy old imported generators and convert them to suit for Indian Power Supply conditions like voltage changes or frequency changes. This is an excellent opportunity to analyze and upgrade the capacity of the generator while re-winding. They may use our consultancy services for such technical modifications of large HV motors and generators.

The author is an Electrical Engineer, and has worked in design and developments of M/s Jyoti Ltd, Kirloskar Electric Company, Crompton Greaves Ltd. etc. Now he is technical consultant. His main interests are in the field of design & development of large induction and synchronous machines and permanent magnet machines. He has published technical papers in National and International journals.

Reference Book:

Electrical India
March 2005, Vol. 45 No. 3