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Starting Frequency Converter SFC D3.1 Redundancy Upgrade Modification for GT Generators

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***Abstract*- The existing system is redundant for SEMIPOL® Excitation Equipment D3.1 (SEE), the system include two channels CH#1 & CH#2 and observed that kept SEE as redundant on both channels but SFC is indicated in CH#1 only. The study of the system and the idea was proposed and requested the manufacturer to give the feasibility of the modification, after deep study the proposal approved as pioneer and innovative idea. The concept of proposed modification is to keep SFC full redundant even after start up, the benefits from modification when any abnormal appeared during running of the machine in one of the channels will not effect of SFC whenever required in the startup. The modification will increase the reliability of the system and availability of the equipment which cause the sustainability for the generation of the power energy. The achievement is the first in the world modification talk place as initiated from Dubai Electricity and Water Authority (DEWA).**

***Index Terms*—SFC, Redundancy, Sustainability.**

I. Introduction

Principles of operation of the Static Frequency Converter is during synchronous starting of the inverter, the mains converter works as a rectifier and passes the active power taken from the mains on to the DC link. The machine converter works in inverter mode and, from the terminal voltage of the synchronous machine, generates a counter-voltage to the link voltage generated by the mains converter from the mains voltage as seen in figure (4). It takes up power from the DC link and passes this on to the synchronous machine.

If the machine is to be decelerated, the machine converter works in rectifier mode and the mains converter in inverter mode. The polarity of the DC link voltage is now opposite to the polarity on synchronous starting. With the same direction of current flow in the DC link, this means that energy is now flowing from the machine into the mains.

The reactor in the DC link here decouples the mains and machine converters. It takes up the voltage differences and smoothens the DC link current.

During the acceleration phase, the starting voltage controller ensures a constant machine terminal voltage.

Current commutation in the machine converter takes place by means of the terminal voltage of the synchronous machine. However, between standstill and a certain minimum speed, the synchronous machine does not generate the voltage necessary for current commutation. In this speed range, commutation is achieved by periodically and temporarily changing the operating mode of the mains converter from rectifier to inverter mode. As a result, the current in the DC link becomes zero. The holding current of the machine converter thyristors is no longer reached, and the blocking capability of the machine converter thyristors is restored after a waiting time of approx. 2 ms. By firing of the subsequent thyristors in the machine converter and driving the mains converter into rectifier mode, the current is connected to the next stator phase of the synchronous machine.

This type of commutation is called chopping mode.

In order to generate the maximum torque possible, the maximum firing angle possible must be set for the machine converter assembly, so that the extinction angle available to the thyristors is only very small.

However, this extinction angle cannot become smaller than the hold-off intervals of the thyristors permits. If the hold-off interval is shorter than the critical hold-off interval of the thyristors, a short circuit occurs which is driven by both the machine voltage and the mains voltage (summed up). This does not lead to any problems in chopping mode because there the current is forced to zero if commutation is to take place. In the case of machine-driven commutation, the firing of the thyristors must be brought forward by a displacement angle (increasing the hold-off interval). Firing of the thyristors at an earlier time increases the distance from the inverter stability limit. In order to enable a sufficient hold-off interval with a large cos ϕ, the displacement angle is varied in a speed and current-dependent manner.

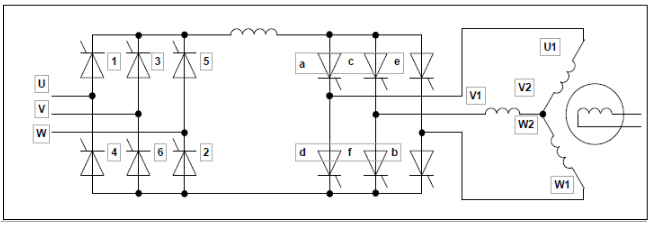

Fig. 1: Simplified presentation of the Static Frequency Converter power section

If, for example, thyristor arms 1 and 6 in the mains converter and thyristor arms a and f in the machine converter a fired, a current flow flows from phase U via thyristor arm 1, the reactor, thyristor arm a, through the stator windings between U1 and V1 back through thyristor arms f and 6 into mains phase V. A magnetic field Φ1 is thereby generated. Both fields, i.e. ΦF and Φ1, generate a torque the magnitude of which is expressed by the following relationship:

$$M \sim \Phi 1 \ \text{x} \ \Phi F \ \sin\delta$$

δ: angle between Φ1 and ΦF

The rotor starts turning and would stop when the cross product Φ1 x ΦF becomes 0, i.e. when the sine of angle δ becomes zero. The turning of the rotor generates a

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three-phase voltage at the terminals of the machine. Its voltage zeros are measured and then determine the time of firing of the next thyristor arm (in this case: arm b) of the machine converter.

Thyristor arm f blocks now, and a current flows through the windings of phases U1 and W1. The resultant stator field moves to the vector Φ2. A torque is generated once again and the rotor continues turning. This process is now continuously repeated. The machine set is accelerated.

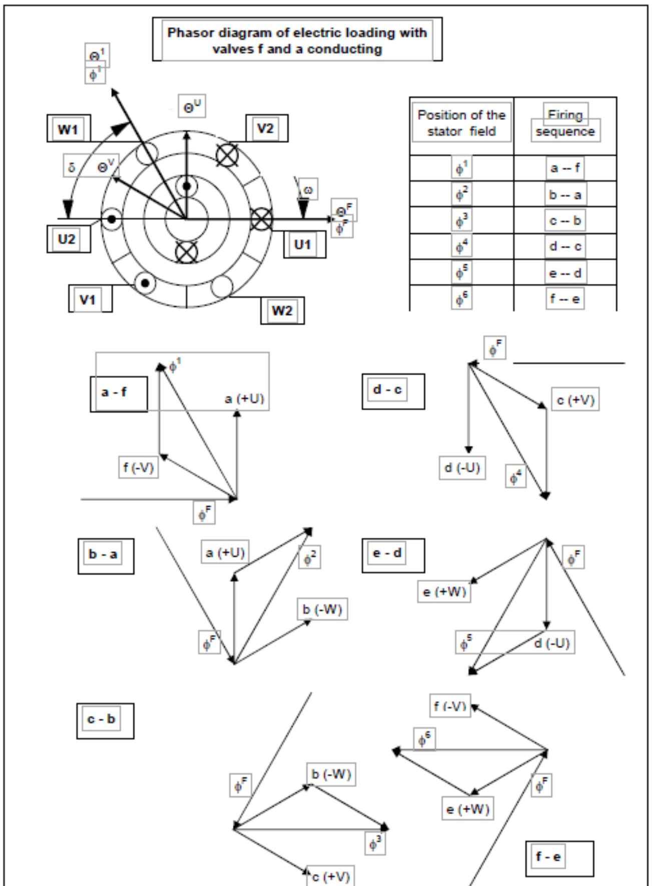

Fig. 2

A three-phase bridge generates a 6-pulse DC voltage from the three-phase voltage connected to its three-phase terminals. If the valves of the bridge arms are thyristors, the mean value of the DC voltage can be reduced even into the negative range by delaying the activation time of the bridge arm in relation to the natural firing time. The natural time of firing of an arm is the time when the diodes would be switched on with a B6 diode bridge, i.e. the time when the voltage across the arm becomes positive. This delay angle is called delay angle Î±. The following relationship exists between the phase-to-phase three-phase voltage UV, the delay angle Î± and the DC voltage Ud:

$$U d = 1.35 \text{ x } UV \text{ x } (\cos \alpha - dx) = 1.35 \text{ x } UV \text{ x } (\sin \beta + dx)$$

The angle $\beta = 180° - \alpha$ is called the angle of advance, with dx considering the commutation between two thyristor arms which does not happen during the time zero.

The minimum permissible delay angle αmin is called the rectifier end position which is determined by the maximum permissible DC voltage. The maximum permissible delay angle αmax is called the inverter end position. This is determined by the available hold-off period and the commutation time at the inverter end position.

If two or more B6 bridges are connected in series or parallel on the DC end and if the three-phase voltage systems at the three-phase connections 30°, 20°, 15° and so forth are phase-displaced, the DC voltage becomes higher-pulse 12, 18, 24 and so forth. [1]

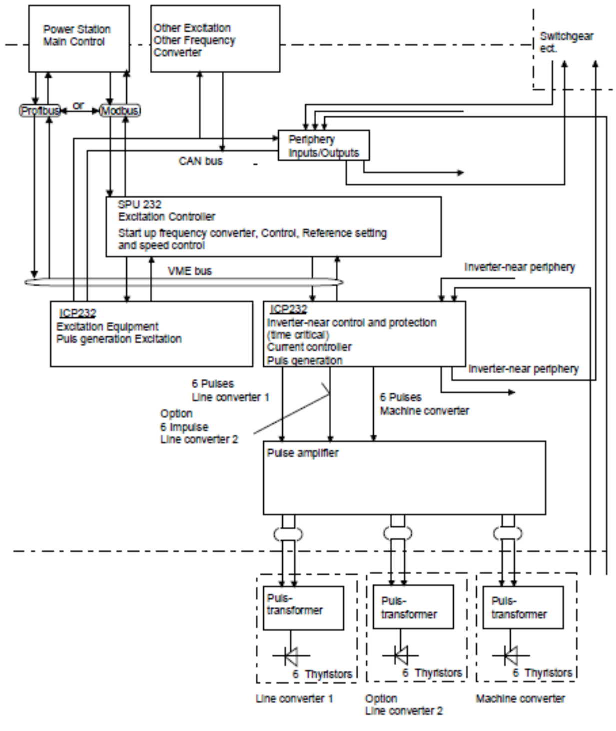

Fig. 3 Communication scheme of the controller

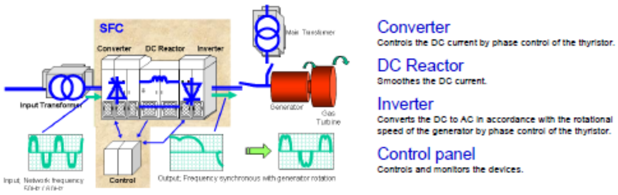

Figure (4) Basic consept of SFC

II. STUDY AND ENGINEERING MODIFICATION

External environmental demands or internally driven performance demands may require a change in the configuration of multicomponent system to maintain functionality and throughput throughout an extended mission [2].

Static Frequency Converter (SFC), for starting of Gas Turbines in DEWA-M Station, are manufactured by M/s Converteam.

SFC starting facility for GTs have no redundancy in control circuit. There is no SFC control channel #2 available. In order to overcome this limitation, SFC redundancy modification was proposed and duly approved vide AFKARI Idea I-2016-12369 [3].

The modification within the software (Switchover between channels) tested by manufacturer General Electric (GE).

The cross-start function also to be modify and execute on site under the pre-condition that two units in one block will be modified.

The current installed software-version is old. High development efforts are needed to update this software to the latest D3.1 version. This update is mandatory to implement all necessary changes in the software. This means that totally new software needs to be implemented, which will result in a partly commissioning of all relevant units.

In the following lines the functional description of the software in headwords:

All units are compact units with 1 SFC and 2 EXC Channels

- Cross start possible between Unit 11 and 12 / Unit 21 and 22 / Unit 31 and 32.
- Software Version in Units EFC3_3153 (1). Software doesn't support a 2nd SFC channel and is too old to update it by this function. So the only solution is to upgrade to the latest software version and adjust it to the Jebel Ali M configuration.

- A new commissioning is to be done as the many functions will change. Also the following components must get software upgrades:

- The SPU Boards
- The ICP Boards
- The touch panels
- The CAN Gateways

- Software in Units must be the same to allow cross start. So if only one unit is upgraded, cross start isn't available until the other unit is upgraded too!

- The new software would allow the following:

- Start own unit with own excitation channel 1 and own SFC channel 1
- Start own unit with own excitation channel 2 and own SFC channel 1
- Start own unit with own excitation channel 1 and own SFC channel 2
- Start own unit with own excitation channel 2 and own SFC channel 2

- If cross start is required between 2 units:
- Start own unit with own excitation channel 1 and other unit's SFC channel 1
- Start own unit with own excitation channel 2 and other unit's SFC channel 1
- Start own unit with own excitation channel 1 and other unit's SFC channel 2
- Start own unit with own excitation channel 2 and other unit's SFC channel 2

- The selection of the desired SFC channel is done on the touch panel.
- The change of the selection only can be done in SFC OFF state.
- If the unit already is prepared or the SFC is ON, the selection cannot be changed.
- Hot swap over for the SFC functions are not supported! So, if the selected SFC or active (start) excitation channel have a fault, the SFC will trip. The selection has to be changed manually and another start trial initiated.
- The selection of the desired SFC channel can also be done by powering down the other channel.
- If one channel is powered down because of problems or service actions both SFC and excitation of this channel aren't available anymore. So, if channel 1 of own unit is powered down, the following functions aren't possible anymore:
- Start own unit with own excitation channel 1 and own SFC channel 1
- Start own unit with own excitation channel 1 and own SFC channel 2
- Start own unit with own excitation channel 1 and other unit's SFC channel 1
- Start own unit with own excitation channel 1 and other unit's SFC channel 2

All the modification approved by Manufacturer after engineering study and make the simulation to verify the proposed modification and going to implement the modification in DEWA-M station and will implemented also for other units as many requests record from other customers as innovation of the power plant and sustainability.

III. Conclusion

The results of the modification lead to improve the existing SFC system and increase the availability which is very important for power system, especially in generation section sustainability requirements.

The modification of the second channel and software upgrading in the SFC system aimed to keep the system full redundancy all the time whenever required, especially during Gas Turbine Generator start up.

References

[1] Power Conversion Company (CONVERTEAM), "Description of the Startup Frequency Converter SFC D3.1)," Doc.-No. 029.950 809.
[2] M. Parris, C. Sharma, and R. Demara, "Progress in autonomous fault recovery of field programmable gate arrays,"
[3] AFKARI System authorized approval for Dubai Electricity and Water Authority (DEWA), ID-2016-12369, 22nd Aug 2016.

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