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REDUCING POWER FLUCTUATIONS ON MARINE POWER PLANTS USING FUZZY LOGIC

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***Abstract*— Marine vessels with diesel-electric propulsion system undergoes severe power fluctuations on the AC grid. These fluctuations cause temperature variations in the battery, energy storage system in this power producer. Due to the temperature variations, this battery gets heated up and ship grid becomes weak. For the stability of this power producer, the estimating parameters such as temperature and state of charge of the battery in the power plant should be maintained. The solution for this problem in power is the battery power smoothing control methods, which is coordinated with the DC/AC ship grid. This paper explores a new smoothing control strategy in marine power plant by using a fuzzy predictive controller with an additional battery. The fuzzy controller is used for estimating the expected values of temperature and state of charge. This control strategy also has a band-pass filter, for the charging and discharging of the battery in this control system. The simulation result shows the proposed control strategy using fuzzy logic provide significant advantages in terms of reducing the fluctuations.**

***Index Terms*—Marine vessels, AC grid, Diesel-electric propulsion system, State of charge, Fuzzy controller.**

I. INTRODUCTION

Due to the large amount of consumers compared to the producers, the marine vessels with diesel electric propulsion system has a weak AC grid. When a load change is applied to this weak grid, the variations in the power will occur and these variations cause the temperature variations. The variations in temperature affect the battery, which is used as the energy storage system in the plant, becomes hot up and fall into default. The temperature variation in the storage system is the major reason of the power fluctuations. In some cases, the environmental and operational conditions become the reason of these fluctuations. The main problems due to these fluctuations are synchronization problems of coordinating new generators to the plants, voltage variations in the heave compensators, variations in voltage supply, diesel electric shaft for motion etc.the figure of diesel electric shaft is shown in Figure. 1

There are mainly three types of propulsion are used in marine vessels. They are gas turbine engine, diesel-electric engine and nuclear propulsion engine. The diesel electric propulsion is commercially used engines, since it has lower fuel consumption, less bunker space and efficient prime mover.

Even the diesel electric engine has more advantages than other engines, they are more expensive and more noise and vibration. These variations and fluctuations can be reduced by using many control strategies. Some are commonly used, but they are not effective in performances. Power redistribution control (PRC) strategy, control strategy with hybrid energy storage and rule based control strategy in HEV [4]-[7] are the some of the control methods for reducing fluctuations in the power plants.

Power redistribution control strategy is used to load fluctuations in marine power plants.In this strategy, there is a powervdistribution controller which has two different strategies for the reduction of load fluctuations. First method is the naetwork frequency deviations and the second one is the generating system torque deviations.

Control strategy for the electric propulsion system with hybrid energy storage is used to reduce the power and torque fluctuations.this control system can achieve the efficiency with some limitations n the control designs.

The rule based control strategy in HEV is used power management algorithms. Power split control and gear shift control are the two control modes in this method. It is mainly used to emphasize fuel economy through optimizations.In some cases, this rule controller shows worst performances.

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Fig.1. Diesel Electric Shaft

Here the paper is describing a power smoothing control method for reducing fluctuation with fuzzy logic. This control hierarchy consists a fuzzy controller with an additional battery and a band-pass filter. Fuzzy controller is designed on the basis of fuzzy logic. Fuzzy controller has robust control and if the model of the system is known to the designer or there is any knowledge about the model the controller in the system can be designed. This adaptive logic system is more precise than other methods. [5] proposed a principle in which another NN yield input control law was created for an under incited quad rotor UAV which uses the regular limitations of the under incited framework to create virtual control contributions to ensure the UAV tracks a craved direction. Utilizing the versatile back venturing method, every one of the six DOF are effectively followed utilizing just four control inputs while within the sight of un demonstrated flow and limited unsettling influences.

The additional battery in the control strategy may arise a problem of increased heat loss. When the heat loss in the battery increases, the battery becomes broken down. The only solution for this problem is by using a band-pass filter. The band-pass filter is used to regulate and control the loss of heat energy.

II. POWER SMOOTHING CONTROL SYSTEM USING FUZZY LOGIC

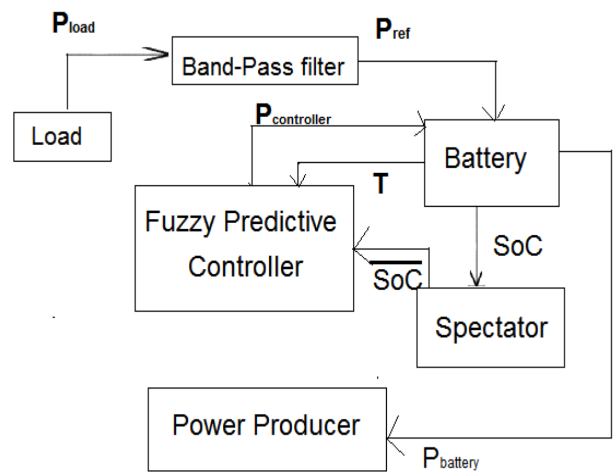

Fig.2. Control Strategy

In this control strategy shown in figure. 2 the power load Pload is the input given to the system and this power is applied to the transfer function, which defines the band-pass filter. The given second order band-pass filter is the combination of first order high-pass filter and low-pass filter. The second order band-pass filter attenuate the high pass signals and low pass signals.

The transfer function of high-pass filter is

$$H_{f1}(j\omega) = \frac{\tau_1 j\omega}{(1 + \tau_1 j\omega)} \quad (1)$$

The transfer function of low-pass filter is

$$H_{f2}(j\omega) = \frac{1}{(1 + \tau_2 j\omega)} \quad (2)$$

Therefore the transfer function of the band-pass filter with n_{cells} is

$$H_f(j\omega) = \frac{\tau_1 j\omega}{(1 + \tau_1 j\omega)(1 + \tau_2 j\omega)n_{cells}} \quad (3)$$

The battery in the strategy may produce lots of heat when charging. Therefore the band-pass filter is used to control the charging and discharging of the battery. The battery is used to determine the temperature and state of charge (SoC), which are the estimating parameters.

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The SoC of the battery can be as [9]

$$SoC=\int \frac{Idt}{Q_{nominal}} \quad (4)$$

The temperature of the battery can be defined by using Newton's law of equation and is given as[1]

$$\frac{dT}{dt}=\frac{hA}{C}(T_{air}-T)+\frac{1}{C}Q_{el} \quad (5)$$

The heat loss in the battery is given as[1]

$$Q_{el}=I^2 R_{battery} \quad (6)$$

From the given equations (3), (4), (5), (6), the equation of the current can be derived. The current I is given as

$$I=\frac{CT-[hAT_{air}-T]}{R_{battery}\,Q_{nominal}SoC} \quad (7)$$

The spectator in the system observes each event in the estimation of the state of charge from maximum value to minimm value.

The internal circuit of the battery can be considered as in figure.3

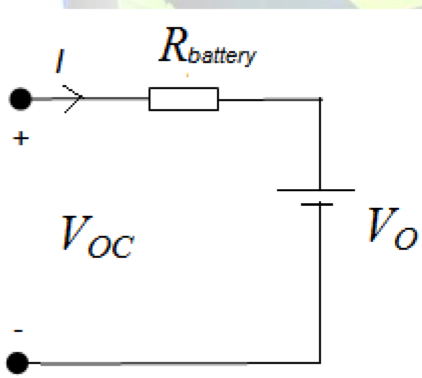

Fig.3. Internal circuit

The internal circuit model of the battery is based on the Thevenin's equivalent circuit model. The voltage Voc is considered as the open circuited and the internal battery resistance $R_{battery}$ is connected in series with the output voltage of the battery, Vo

Power from the battery, Pbattery can be derived from the circuit diagram as

$$Pbattery= I(Vo+R_{battery}I) \quad (6)$$

From the control block diagram that means control strategy, the Pbattery is given as

$$Pbattery=Pref+ Pcontroller \quad (7)$$

Using the fuzzy logic, the Pcontroller can be designed for estimating the control parameters temperature and SoC.

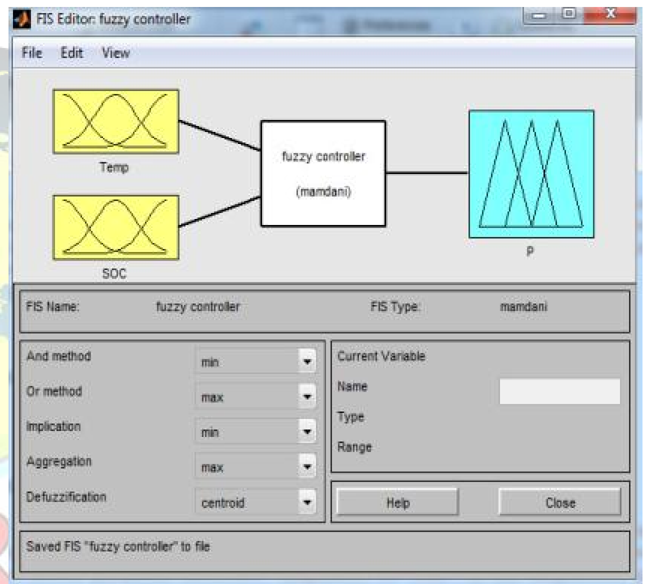

Fig.4. Design of fuzzy controller

The fuzzy controller is designed with a set of fuzzy rules. The rules are in the form of implication, that is IF…..THEN… rules and designed on the basis of mamdani

The power from the system after smoothing is given to the power producer is used for compensating flucatuated power.The power Pbattery is used for compensating and which is derived from the reference power driven from band-pass filter and power from the fuzzy predictive controller.

III. INPUT ATTRIBUTES

For implementing the system the input parameters are:

Maximum value of SoC is 50% and minimum value of that is 100%.

The temperature value is in between 0^0C to 35^0C.

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The temperature in the air is between -2^{0}C to 37^{0}C, since at ocean level, the surrounding Temperature is in this range.

The value of the internal resistance of the battery, $R_{battery}$ is very small, so it can be neglected.

IV. RESULTS

The SoC and temperature of the model after simulation is shown in figure.5.For the stability of the performance of the power producer, the SoC should be 50% to 100% and temperature should be 0-35^{0}C

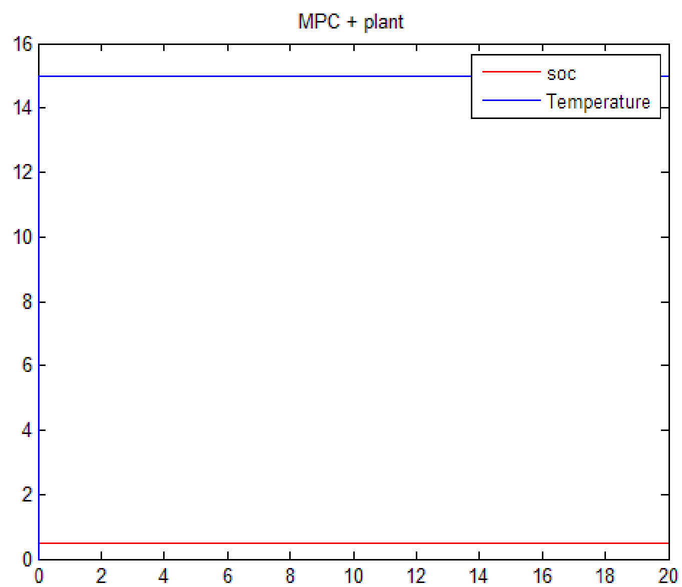

Fig.5. SoC and Temperature

The SoC and temperature variations which are considered as errors during power fluctuations at an instant is shown in figure.6 and 7

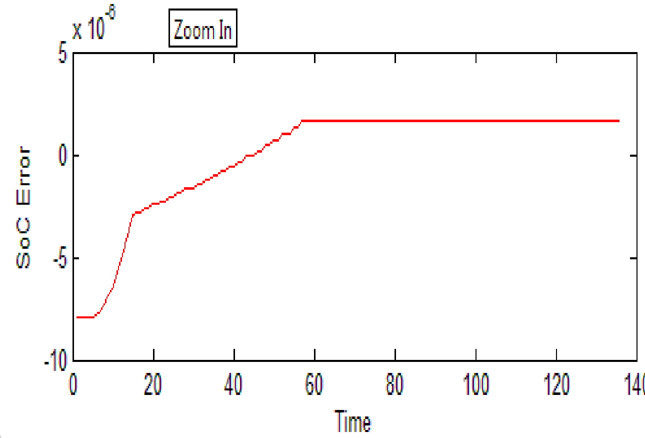

Fig.6. SoC variations

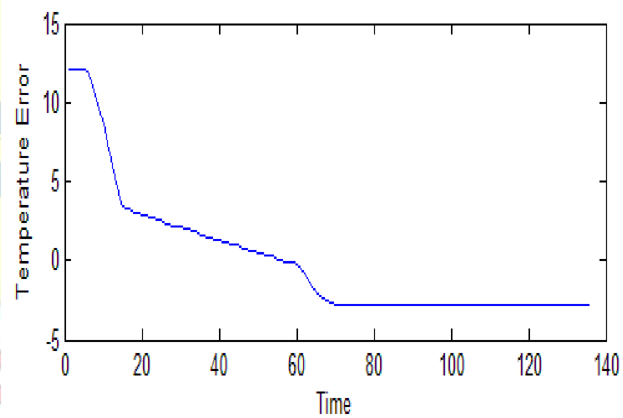

Fig.7.Temperature variations

V. CONCLUSION

The power fluctuation is the one of the major problems in the marine power plants. To avoid these the fluctuations, the temperature and state of charge should in operational limits. The power smoothing strategy in this paper described is more effective and gives controlling parameters within ranges. Since the given control strategy is implemented using fuzzy logic. The fuzzy logic is more reliable and user friendly than other algorithms. The state of charge and temperature of the battery is derived from this model is within operational limits.

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