The development of control and monitoring system on marine current renewable energy
Case study: strait of Toyapakeh - Nusa Penida, Bali

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Abstract. Control and monitoring system is a continuous process of securing the asset in the Marine Current Renewable Energy. A control and monitoring system is existed each critical components which is embedded in Failure Mode Effect Analysis (FMEA) method. As the result, the process in this paper developed through a matrix sensor. The matrix correlated to critical components and monitoring system which supported by sensors to conduct decision-making.

1. Introduction
Strait of Toyapakeh is located between Bali and Nusa Penida island (shown in Fig. 1). This strait has a good potential of Marine Current energy. Based on the measurement which has been conducted by the researchers in 2015, the Strait of Toyapakeh has the potential Marine Current energy up to 320 mw. The wave amplitude in this strait reached more than 2.6 meters. As other regions in Indonesia, tides type is twice up and down per day [7]. From the reason, Strait of Toyapakeh can be used as the alternatives area to generate the Marine Current energy.

The basic principle of marine current energy is to convert kinetic energy to electricity [7]. To support the conditions, communication infrastructure has an important role. The communication infrastructure includes control and monitoring system of Marine Current energy. As the standard of the research, communication for monitoring and control is based on international standard IEC 61400-25. The standard is can be applied on Marine Current Renewable Energy.
2. Methode scheme of research

Design review is crucial in order to determine failure potential and position by Failure Mode Effect Analysis (FMEA) method. In order to, FMEA describes each part of Marine Current components specifically. Then, the process is continued in control and monitoring system. The design of control and monitoring system of Marine Current Renewable are described in picture bellow:

![Figure 2. The Scheme of Control and Monitoring System](image)

According to the scheme, specified function of control and monitoring is designed as early warning system. Mostly, the functions work as local and long distance area. To support long distance area, remote system is required as data communication by telemetry. In this paper, control and monitoring system is divided into data monitoring, data analysis and processing. The physical data monitoring are split as follows:

- Direction and wind speed
- Oceanography.
- Mechanical condition and structure
- Bending Load, torsional, and vibration.
- Stress, strain, and displacement.
- Temperature operation and gearbox.
- RPM of main shaft.
- Position / turbine orientation relative to platform.
- Voltage characteristic
- The quality of power
- additional data monitoring
- relative motion platform to the reference coordinate

Based on the description, the type of sensors level position can be determined on the table follows:

| No. | Sensor/transducer       | Level Position                      | Explanation                    |
|-----|-------------------------|-------------------------------------|--------------------------------|
| 1   | Wind speed sensor       | Highest position of platform        | Wind Speed                     |
| 2   | Wind direction          | Highest position of platform        | Angina speed                   |
| 3   | Rainfall transducer     | Highest position of platform        | Humidity                       |
| 4   | Air temperature sensor  | Highest position of platform        | Wet and dry temperature        |
| 5   | Relative humidity sensor| Highest position of platform        | Humidity                       |
| 6   | Evaporation rate        | Highest position of platform        | Evaporation                    |
| 7   | Sea water current meter | As level as turbine                 | Speed water flow moves the turbine |

For mechanical and structural conditions, the type of sensors level position can be determined on the table follows:

The characteristics voltage characteristic can be measured from the side of the power station as well as from the side of the load. The signal information characteristic of the electrical voltage is available on the system and plant distribution. Thus, the control system and monitoring lives the signals and process them. As for signals that are required are as follows:
Table 2. Sensor Level for mechanical and structural conditions.

| No. | Sensor/transducer       | Level Position                  | Explanation                                           |
|-----|-------------------------|---------------------------------|-------------------------------------------------------|
| 1   | Rotary encoder          | Main shaft turbine              | Turbine speed rotation                                |
| 2   | Rotary encoder          | Generator shaft                 | Generator speed rotation                              |
| 3   | Rotary encoder          | Motor shaft turbine lifting mechanism | Speed rotation of motor lifting mechanism             |
| 4   | Rotary encoder          | Shaft turbine lifting mechanism  | Angel position and speed rotation of turbine lifting mechanism |
| 5   | 3-axis accelerometer    | Far-end turbine main shaft       | Mechanic vibration and displacement                   |
| 6   | 3-axis accelerometer    | Mid-end turbine main shaft       | Mechanic vibration and displacement                   |
| 7   | 3-axis accelerometer    | Near-end turbine main shaft      | Mechanic vibration and displacement                   |
| 8   | Dynamic torque sensor   | Turbine main shaft               | Torque of turbine shaft                               |

Table 3. Sensor level for voltage characteristics

| No. | Sensor/transducer       | Level Position                  | Explanation |
|-----|-------------------------|---------------------------------|-------------|
| 1   | Voltmeter               | in the plant and load           | Power quality |
| 2   | Ampere meter            | in the plant and load           | Power quality |
| 3   | Current transformer     | in the plant and load           | Power quality |

Additional monitoring data to describe the movement, position and orientation platforms are obtained on Table 4:

Table 4. Sensor level of additional monitoring data

| No. | Sensor/transducer       | Level Position | Explanation                      |
|-----|-------------------------|----------------|----------------------------------|
| 1   | Hybrid IMU sensor: accelero, gyro, magneto | Metacenter      | Platform moving in 3D            |
| 2   | GPS and hybrid IMU      | afores plate    | Platform position and orientation |

3. Result and discussion

Data processing is change the value based on factors calibration of measurement or change data formats input to others format. In accordance is needed by applying integration, differentiation, Fourier transformation or other methods of data input. Data analysis is conducted to obtain the condition of the system based on sensor data which has been adapted to reflect the needs. Analysis data divided into:

1. Data analysis directly, measured to:
   - Temperature gearbox
   - Speed of main shaft

2. Data analysis indirectly, measured to:
   a) The main shaft torsion: increase or decrease of torsional load can is predicted based on the ratio between the speeds of water flow
      \[ f_v = \frac{v_w}{v_p} \]. In order side, speed blades at a certain point \( v_p \) which described as the factor ratio
      If the \( f_v \) up, it can be considered that the load of main torsional rose as well.
   b) The results of the analysis show unreflect on normal operations will be forwarded to control and algorithm alarm (warning or early warning).

Control system undertakes the function of control, in order to the process of the system and equipment safety. Control system works on commandment which embedded in processor to a condition reading sensors mounted on equipment on demand. The process control system started with a source of up to a produced output. Therefore, it is divided into the critical component, those are:

1. Battery.
   Control and monitoring system of battery in several conditions, such as:
   c) Short circuit
   d) Overload
e) High temperature of battery
2. Bearing
3. Gearbox
4. Inverter
5. Generator
6. Power control
7. Main shaft
8. Shaft main drive
9. Turbine

According to critical component in the research developed through a matrix sensor. The matrix correlated components critical and monitoring system which supported by sensors to do decision-making. The matrix sensor of the components can be determined on the tables below:

**Table 5. Matrix Sensor of Current**

| Correlation of Sensor and Reaction | Current Sensor (Up) | Current Sensor (Down) |
|----------------------------------|---------------------|-----------------------|
| Gearbox Temperature Sensor (Up)  | ALARM & ACTUATOR ACTIVE | ALARM |
| Gearbox Temperature Sensor (Down) | ALARM                  | -                   |
| Sensor of Blade Speed Rotation (Up) | ALARM & ACTUATOR ACTIVE | ALARM |
| Sensor of Blade Speed Rotation (Down) | ALARM                  | -                   |
| Sensor of Shaft Speed Rotation (Up) | ALARM & ACTUATOR ACTIVE | ALARM |
| Sensor of Shaft Speed Rotation (Down) | ALARM                  | -                   |
| Sensor of Load Torsional (Up)    | ALARM & ACTUATOR ACTIVE | ALARM |
| Sensor of Load Torsional (Down)  | ALARM                  | -                   |

**Table 6. Matrix Sensor of Voltage**

| Correlation of Sensor and Reaction | Voltage Sensor (Up) | Voltage Sensor (Down) |
|-----------------------------------|---------------------|-----------------------|
| Gearbox Temperature Sensor (Up)   | ALARM & ACTUATOR ACTIVE | ALARM |
| Gearbox Temperature Sensor (Down) | ALARM                  | -                   |
| Sensor of Blade Speed Rotation (Up) | ALARM & ACTUATOR ACTIVE | ALARM |
| Sensor of Blade Speed Rotation (Down) | ALARM                  | -                   |
| Sensor of Shaft Speed Rotation (Up) | ALARM & ACTUATOR ACTIVE | ALARM |
| Sensor of Shaft Speed Rotation (Down) | ALARM                  | -                   |
| Sensor of Load Torsional (Up)     | ALARM & ACTUATOR ACTIVE | ALARM |
| Sensor of Load Torsional (Down)   | ALARM                  | -                   |
Table 7. Matrix Sensor of Flow Speed

| Correlation of Sensor and Reaction | Sensor of Flow Speed (Up) | Sensor of Flow Speed (Down) |
|-----------------------------------|---------------------------|----------------------------|
| Gearbox Temperature Sensor (Up)   | ALARM & ACTUATOR ACTIVE   | ALARM                      |
| Gearbox Temperature Sensor (Down) | ALARM                     | -                          |
| Sensor of Blade Speed Rotation (Up) | ALARM & ACTUATOR ACTIVE | ALARM                      |
| Sensor of Blade Speed Rotation (Down) | ALARM                     | -                          |
| Sensor of Shaft Speed Rotation (Up) | ALARM & ACTUATOR ACTIVE | ALARM                      |
| Sensor of Shaft Speed Rotation (Down) | ALARM                     | -                          |
| Sensor of Load Torsional (Up)     | ALARM & ACTUATOR ACTIVE   | ALARM                      |
| Sensor of Load Torsional (Down)   | ALARM                     | -                          |

4. Conclusion
1. The design of control and monitoring system needs to involve failure effect analysis to determine each critical component.
2. The critical component that developed through matrix sensor.
3. The matrix correlated critical components and monitoring system which supported by sensors to do decision-making.

5. References
[1] A. G. Marbun, Failure Mode Implementation and Effect Analysis (FMEA) to Increase Reliability of Boiler Pipe, Jakarta: Teknik Industri, Universitas Mercubuana, 2013.
[2] D. Isdarto, Risk Analysis of Operational Failure by Risk Failure Mode and Effect Analysis, Surabaya: Magister Manajemen Teknologi, Institut Teknologi Sepuluh Nopember, 2014.
[3] K. B. Artana, Risk Assessment Subsea Gas Pipeline, Surabaya: Guna Widya, 2013.
[4] M. Mraz, FMEA-FMECA, Ljubljana: Ljubljana Spring, 2005.
[5] Tuncel and Alpan, Risk Assessment and Management for Supply Chain Networks: Case Study, Izmir: Dokuz Eylul University, 2010.
[6] A. P. Adnyasari, "Geography Condition," Pemerintahan Kabupaten Klungkung, 9 11 2015. [Online]. Available: http://www.klungkungkab.go.id/index.php/profil/14/Kondisi-Geografis. [Accessed 2 12 2015].
[7] T. P., "Basic Design of Marine Current Renewable Energy, case study: Strait of Toyapakeh," LPPM ITS, Surabaya, 2015

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